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NEHALEM R.

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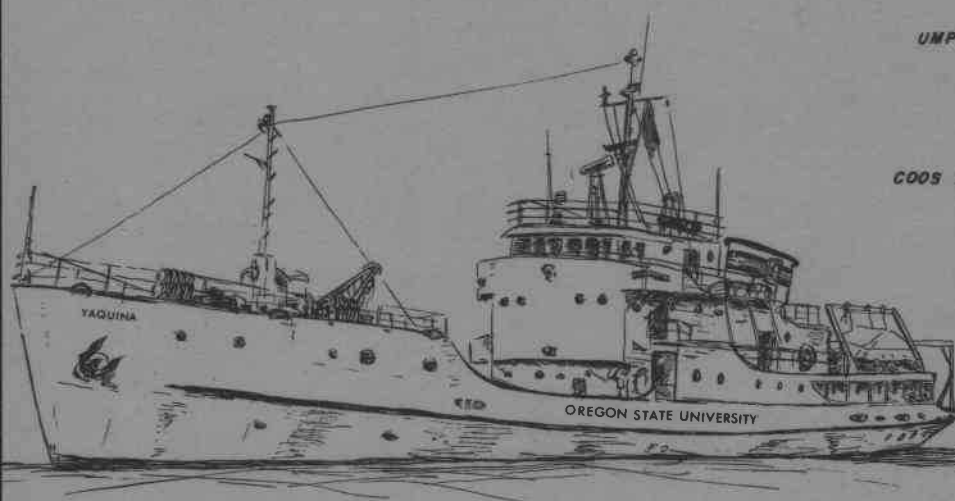
YAQUINA R.

ALSEA R.

SIUSLAW R.

UMPQUA R.

COOS BAY



## RESEARCH ACTIVITIES

1 October 1966  
through  
31 March 1967

Edited by  
Sally Kulm  
and  
Diane Frischknecht

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Progress Report No. 19

Reference 67-5

Department of Oceanography  
School of Science  
Oregon State University  
Corvallis, Oregon 97331

Wayne V. Burt  
Chairman

Progress Report No. 19

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## PHYSICAL OCEANOGRAPHY

### Atmospheric Effects on Incoming Solar Radiation in a Tropical Marine Environment - Quinn, Burt, Neal

Two small atoll islands, Wake and Canton, have been selected for a study on radiation in a marine environment. Daily synoptic weather analyses taken from July 1957 through June 1958 during each daylight hour are being used. All atmospheric and radiation data have been entered on punch cards for later use on the CDC 3300 computer.

We have made a preliminary study of the atmospheric and radiation effects on Canton Island. We have been able to investigate data from unusual weather conditions during the period described above. A comparison between solar radiation transmission under disturbance and non-disturbance type weather conditions in the trough has been made. Conclusions of this preliminary study are being submitted for publication in a paper entitled "Weather and Solar Radiation Reception in the Equatorial Trough."

### Seiching in Yaquina Bay - Gilbert, Pattullo

During 1966 a study of the seiche in Yaquina Bay was undertaken. Records from a permanent tide gauge indicate 10-16 minute and 22-26 minute period seiches are most likely to occur during the summer. Portable tide staff data verified the existence of 2-10 minute seiche which was most prevalent during the winter. These periods were expected for an estuary of Yaquina Bay's dimensions.

The seiching was preceded by either local winds from the west or a frontal-high pressure area passing at sea. Barometric fluctuations also preceded such activity, but seiching did not always occur after such a change.

No large amplitude oscillations were observed. Displacements were the order of centimeters to tens of centimeters throughout.

### Water Masses Contributing to Oregon Coastal Waters - Blanton, Pattullo

The temperature, salinity, and oxygen characteristics of waters adjacent to the Oregon coast are being analyzed in order to derive the possible sources of these waters. The circulation responsible for the mixing along the American West Coast of the Subarctic, North Pacific Central, and Pacific Equatorial Waters appears not to be as simple as previously thought. There is evidence that the waters between 600 and 1200 meters undergo some modification from a warmer and more saline water to the south and west. The locations at which various waters are entrained into the deeper layers off Oregon is the subject of our present research.

Principal data sources for this research are the cruises of NORPAC 55, California Cooperative Fisheries Investigation Cruises, and hydrographic data from the Department of Oceanography at Oregon State University.

#### Hydrography and Dynamics of the Alaskan Stream - Favorite, Pattullo

The Alaskan Stream, an extension of the Alaskan Current, flows westward along the south side of the Aleutian Islands. At Attu Island it divides, sending one branch northward into the Bering Sea and the other southward into the western North Pacific Ocean and the eastward flowing Subarctic Current. Having a maximum geostrophic speed in excess of one knot and a volume transport varying between  $5$  and  $15 \times 10^6 \text{ m}^3/\text{sec}$ , the Stream advects relatively warm, dilute, surface water from the Gulf of Alaska westward and greatly influences water properties near the Aleutians. Thus, it must be considered an important current system of the North Pacific Ocean. Comparisons of volume transports and integrated wind-stress transports show a good correlation and indicate that observed features such as depth, width, and velocity of the Stream might be predicted if a physical model of the system could be devised. Studies are in progress on the properties of the water available for the Stream, the properties of other waters through the area of flow, the nature of functional forces, the rate of change of planetary vorticity, and the means by which vorticity is diffused across the Stream. Similarities between absence conditions and those predicted by Rossby's wake-stream theory are interesting and encouraging.

#### Current Measurements in Shelf Waters - Collins, Pattullo

Time series of current velocity, temperature, and wind have been divided into three frequency domains with numerical filters.

Low frequencies ( $0-1/2$  cpd): wind can linearly account for as much as 90% of the variance of current velocity time series. Shelf waters appear to respond more completely to changes in longshore wind at frequencies of 5.0 and 2.5 days.

Intermediate frequencies ( $1/2-6$  cpd): semidiurnal, diurnal, and inertial frequencies contain 25-75% of the variance of this domain.

High frequencies ( $6-144$  cpd): temperature oscillations with periods of 15 minutes and 40 minutes have been noted.

### Tide Gauge Installation - Pattullo, Pittock

A Fisher and Porter Analog to Digital Tide Recorder was installed on the Marine Science Center pier on 29 January 1967. A new tide staff with both meter and foot scales was also located on the pier. The tide staff elevation was connected by a level loop with three known USC&GS bench marks located ashore.

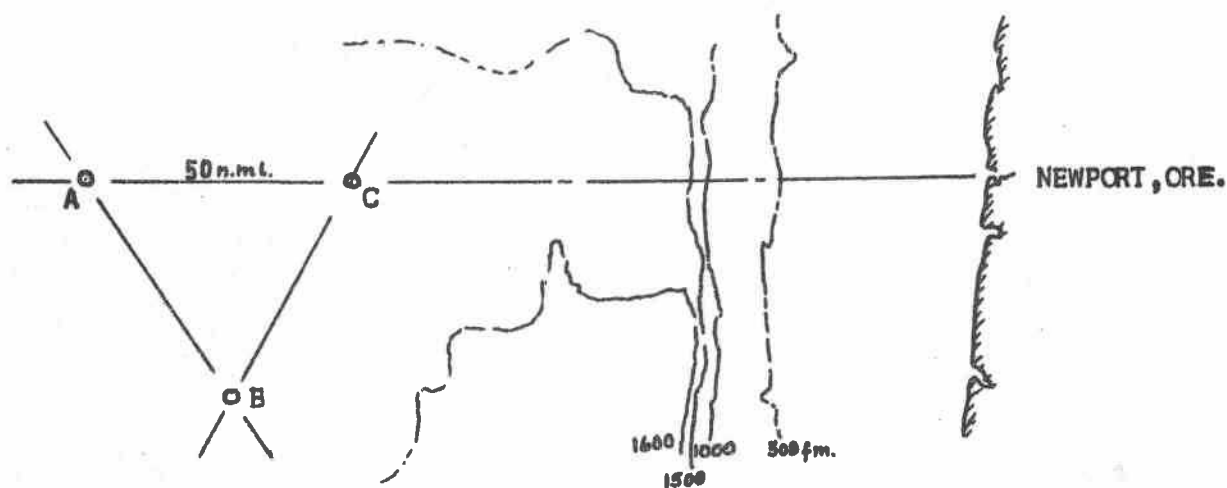
The tide gauge was then placed in operation by setting the time recorder to the correct time and by setting the gauge to read the water level as indicated on the tide staff. Mr. Thayer was designated as tide observer and assumed operation of the gauge. The overall responsibility for the gauge has been assigned to Mr. Young, Oceanography Section, Marine Science Center.

### Hydrography - Neshyba

Analysis of the triangular station data, taken on cruise 6610 (October 1966) is virtually complete. One feature that has proved interesting is the correlation of vertical deviations of temperature from the mean against the vertical deviation of specific volume from its mean. (By mean is meant the 24-hour mean.) These correlations range from very good to very bad; however, in all cases, the removal of a few points from each correlation run resulted in significant correlation. The implication, though not yet well established, is that vertical temperature structure variation can be substituted for vertical density structure variation at 24-hour stations. A second try at this same triangular station network during March was only partially successful due to bad weather.

Another interesting analysis of the triangular station data was performed; four sets of casts were selected such that the times of casts were about the same time of day at all three stations. Results of current computations are shown in Figure 1. At four different times of day, the geostrophic current picture shows four different distributions. The implication is that the tidal forces are to some extent represented in the baroclinic flow field. The distribution of currents computed from the time-averaged-mean-station data is also shown and is taken to represent the flow field corrected for internal wave and tide variations. Analysis now in progress deals with the momentum balance of the triangular station data.





Location of three 24-hour hydrographic stations, spaced 50 n.m.l., off the Newport, Oregon, coast, November 1 - 4, 1966.

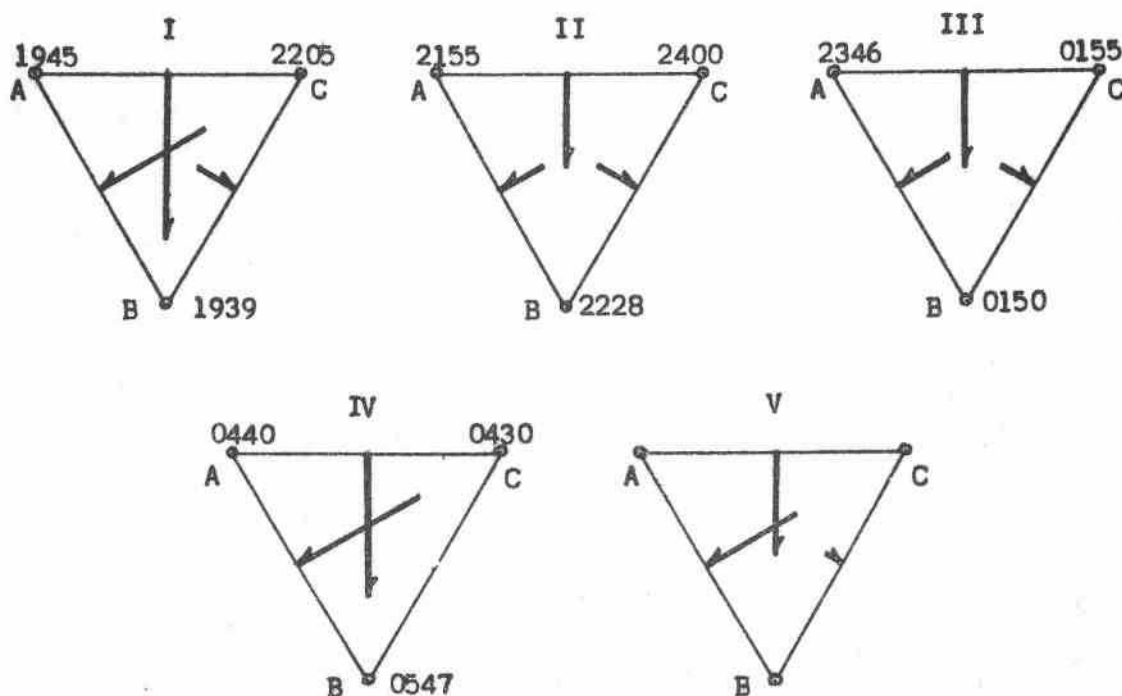


FIGURE 1. A total of eighteen separate casts were made at three 24-hour stations as shown. From these, four sets were obtained such that the times of casts within each set were at about the same time of day. Diagrams I - IV show the computed surface velocities relative to the 600 decibar level (level of no horizontal motion as defined by Defant, 1961). The computed surface velocities in diagram V are obtained from time averaged temperatures and thermosteric anomalies at each of the three 24-hour stations.

### Hydrographic Capability of the R/V YAQUINA - Neshyba

A proposal has been submitted and partially funded by ONR to upgrade the hydrographic capability of the R/V YAQUINA. The initial funded phase involves the installation of:

- a) A central data logging and computation facility. This will incorporate a PDP-8/S Computer, now on hand, in conjunction with other equipment soon to be ordered. A diagram of the proposed facility is shown in Figure 2. The former dry laboratory on the YAQUINA is being remodeled to a completely electronic laboratory.
- b) A continuous Salinity-Temperature-Depth sensor system. At present, engineering evaluation of the several available STD systems is being performed so that the actual system procured will best integrate with the proposed electronic data facility. A new winch and boom are being designed for the STD; we are attempting a hydraulic design which will permit interchange of the winch between the YAQUINA and the CAYUSE (an 80-foot vessel to be obtained by the Department).

The second phase of the proposal, to be funded later this year, involves the addition of the following capabilities:

- a) Deep ocean current measurements. A set of two self-recording deep-water current meters, together with associated acoustic and timed-release mechanisms, high-pressure buoys, and radio location apparatus are to be purchased. Emphasis is placed on current meters whose records can be immediately processed aboard ship. This capability will provide 20- to 22-hour deep current measurements to accompany 24-hour hydro-station data.
- b) Towed physical-chemical sensor. This unit is to provide pH and oxygen sensor data, in addition to temperature and depth data, while underway. Preliminary designs for a depressor which will porpoise the sensors vertically through an upper layer of about a 300-meter thickness are complete. This work is a continuation of a dissertation program by Mr. Albin, under the direction of Dr. Freund, Department of Chemistry. A block diagram of the proposed system is shown in Figure 3.

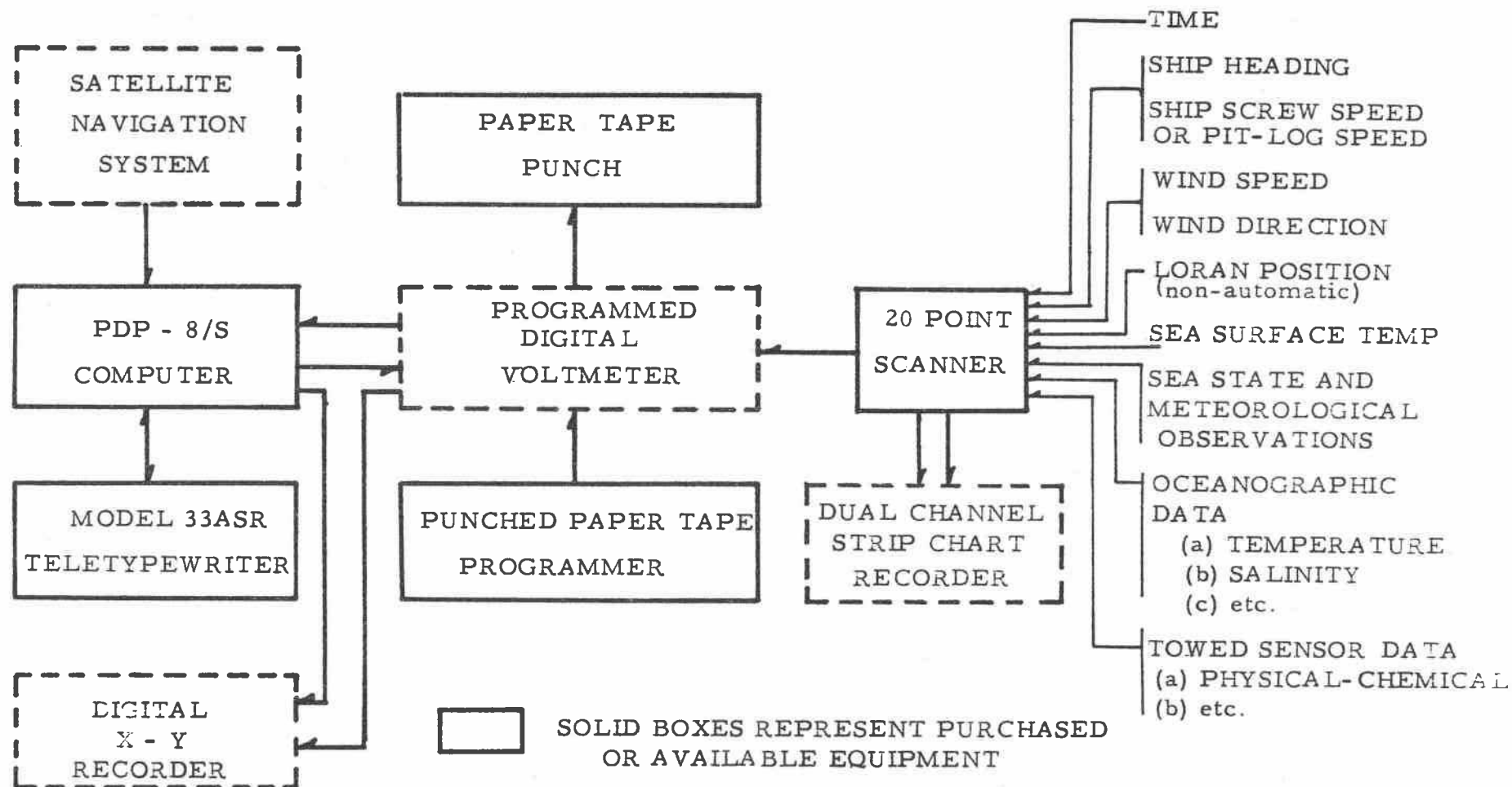


FIGURE 2. PROJECTED ELECTRONIC DATA ACQUISITION AND PROCESSING SYSTEM FOR THE RESEARCH VESSEL YAQUINA

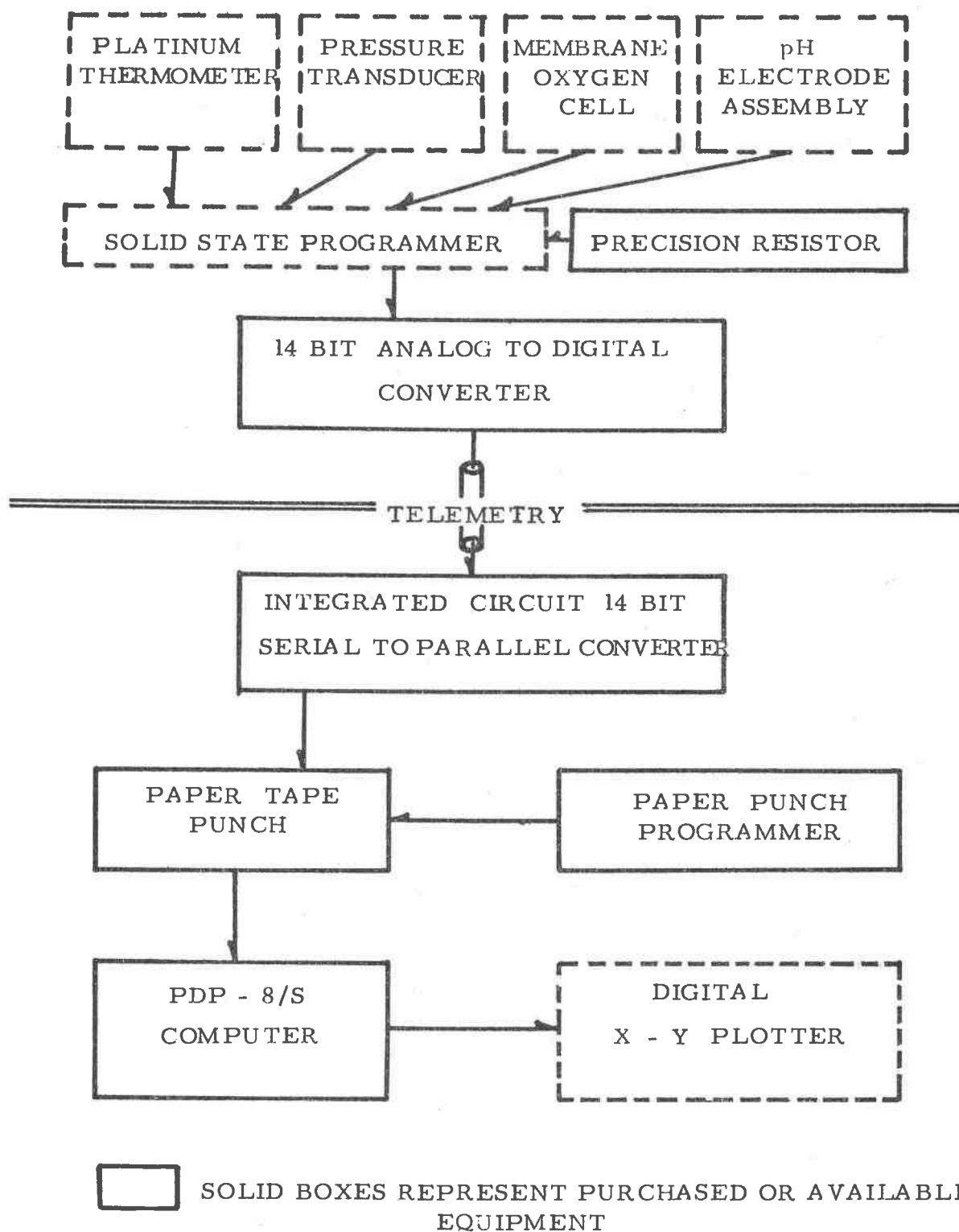


FIGURE 3. PROJECTED PHYSICAL - CHEMICAL DATA ACQUISITION SYSTEM FOR THE RESEARCH VESSEL YAQUINA

### Northwest Oceanographers Ship Panel - Neshyba

A Northwest Oceanographers Ship Panel has been organized by six regional educational institutions and federal agencies to coordinate the scheduling of oceanographic research voyages. The six participants are:

Oregon State University -- Vessel YAQUINA  
 Regional C&GS, Seattle -- Several Vessels  
 Bureau of Commercial Fisheries -- Several Vessels  
 Pacific Oceanographic Laboratory (ESSA)  
 University of Alaska -- Vessel ACONA  
 University of Washington -- Vessel TAMMY THOMPSON

In addition, Canadian oceanographers will be represented as official observers.

A review of ship-use plans will begin immediately and is expected to affect the vessels' usage next year. It is hoped that a cooperative effort will provide more effective use of vessels by combining cruises and using ships for joint projects. All coordinated scheduling will be subject to approval by directors of the participating organizations.

### Oceanography of Shelf Waters - Pattullo, Smith, Pillsbury, Mooers, Cutchin

The array of recording current meters and thermographs is being readied for a spring installation to study the dynamics of shelf waters during the early upwelling season. Three strings, each consisting of a current meter and a thermograph at 20m depth and a current meter at 40 or 60 m depth will be placed on the continental shelf off Depoe Bay, Oregon, from early May to mid June. The location will be in the same region as the installation last summer, which recorded the shelf water dynamics near the end of the summer upwelling period.

Reduction of the data from the late summer/fall installation is being completed and time-series analysis of the records should begin in a few weeks. Some results of an anchor station occupied during that study will be reported in the April 1967 AGU meeting in Washington, D. C. The abstract of the paper "Dynamical structure in an upwelling frontal zone" by Mr. Mooers and Dr. Smith follows:

During the late stages of upwelling, a series of hydrographic and current velocity profiles were taken through the pycnocline, halocline, and thermocline over a lunar day on the continental slope off Oregon. It has been suggested that the temperature inversion in this region at this season is related to frontogenesis (Pattullo

and McAlister, 1962). Two pycnoclines were present, the most intense at 15 to 30 m, the other at 60 to 100 m. A temperature inversion of several tenths of a degree (C) at  $80 \pm 20$  m and subsurface maxima in the horizontal current speed at 30 to 50 m and 70 to 90 m were characteristic. The Richardson number ranges from 5 at 5 m to 40 at 35 m and from 1 to 4 from 50 to 150 m, i. e., dynamic stability, was low throughout the inversion layer. Stability oscillations, or internal cellular waves, are a possible associated mechanism commonly observed in coastal waters. The profile of the Vaisala-Brunt frequency,  $N_1$ , suggests a three-layer model:  $H_1 = 15$  m,  $N_1 = 0.01 \text{ sec}^{-1}$ ;  $H_2 = 15$  m,  $N_2 = 0.03 \text{ sec}^{-1}$ ;  $H_3 = 540$  m,  $N_3 = 0.01 \text{ sec}^{-1}$ , where  $H_i$  is the layer thickness. This is directly analogous to the atmospheric case in which internal gravity waves transfer energy across a thin stability layer to the ionosphere (Gossard, 1962).

Figure 4 is a plot of the temperature field for one lunar day at 25 miles off Depoe Bay. The lightly shaded region indicates the anomalous temperature zone. The heavy dark line indicates the depth of the subsurface temperature maximum, while the solid circles locate the depth of the instantaneous speed maximum.

Figure 5 shows the vertical profiles of the speed of the vector mean and the mean of the scalar speed at 25 miles off Depoe Bay over the same time period as Figure 4, using 17 profiles of data. It is notable that the speed is of low variability at 125 meters and of high variability at 85 meters. Thus there is an apparent causal relation between the depths of the temperature maximum, of the instantaneous maximum speed, and of the maximum variability in current speed. Also noteworthy is that this is the depth of the subsurface maximum salinity gradient and consequently a secondary maximum in static stability.

#### Sea Level Studies - Smith, Mooers

The statistical study of sea level on a time scale of one-to-ten days is continuing. There are several phases to this study besides the statistical descriptive representation of sea level variations along the Oregon coast.

The statistical search of 1933-34 tide gauge records for continental shelf waves has been fruitful. Continental shelf waves are small amplitude (cm), long (1000 km), very low frequency (periods of several days) waves that progress parallel to the coast. They have previously been observed only along the Australian shelf (Hamon) and possibly along the Japanese shelf (Shoji). Robinson (1964) and Mysak (1967) have given theoretical models.

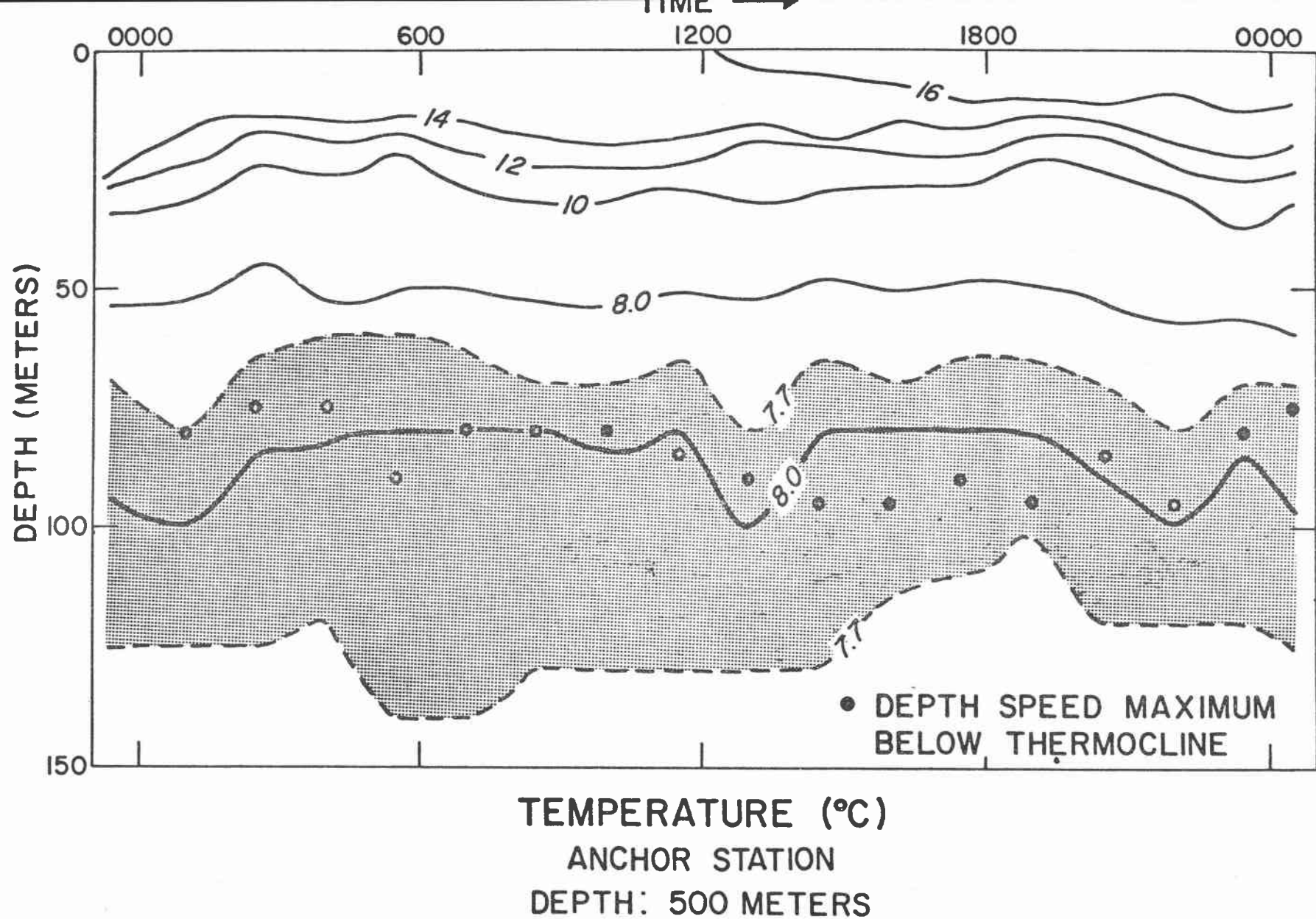


Figure 4. Temperature field for one lunar day 25 miles off Depoe Bay, Oregon

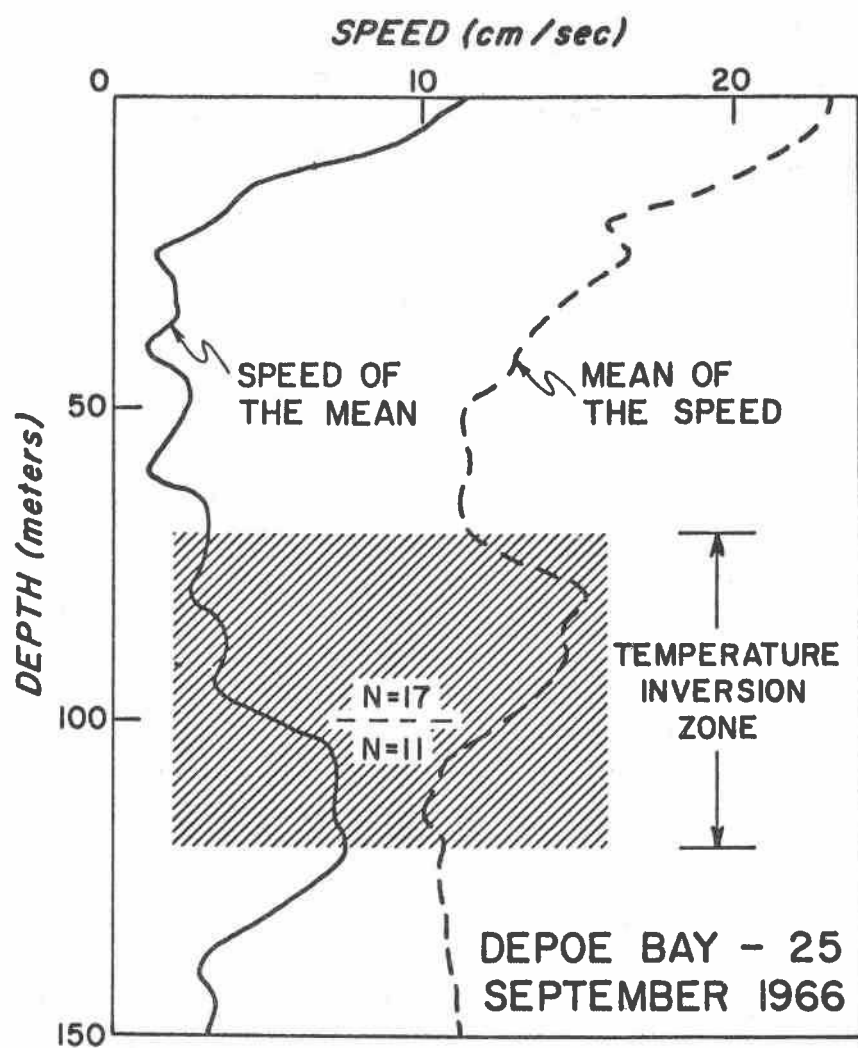


Figure 5. Speed of vector mean and mean of scalar speed at 25 miles off Depoe Bay, Oregon.



From spectral analysis of sea level data from tide gauges along the Oregon coast, we have evidence of the continental shelf waves along this coast. The energy spectrum for summer sea level (see Figure 6) shows peaks at about 0.1 and 0.3 cpd. The barometer factor, calculated from the spectra and cross-spectrum of sea level and atmospheric pressure, shows an anomalously large barometric factor in the vicinity of 0.3 cpd. Estimates of shelf resonance based on Robinson's model, using shelf and atmospheric pressure spatial parameters, indicate the possibility of shelf waves resonant on the shelf with three to four day periods. Coherence squared and phase obtained from the cross-spectra of sea level at several tide stations along the coast indicate high coherence at 0.3 cpd with the wave traveling from south to north (Figure 7), consistent with the continental shelf wave hypothesis. The phase speed is in agreement with Mysak's model, which takes into account the sloping shelf and stratification.

An abstract of a paper to be given by Mooers and Smith at the Mean Sea Level Symposium in Washington, D. C., in April is given below:

In the course of a statistical study of sea level on a time scale of one-to-ten days, correlation and spectral analyses are used for the characterization of the observed processes. There are two phases to this study:

- 1) A statistical-descriptive representation;
- 2) An examination of the inherent statistical predictability.

Tidal and atmospheric pressure records from several Oregon stations are analyzed. A comparison of tidal suppression by two different types of low pass numerical filters is made; then, a comparison is made with data in which periods greater than ten days have been suppressed by a high pass filter. The apparent in-phase barometric factor is given as a function of frequency; the average over frequency differs from a strictly one-to-one isostatic response in the summer but not in the winter season. The use of these techniques illustrates how it is possible to extract information from sea level records for studying short term sea level prediction and time-dependent, dynamical motion on time and space scales related to such phenomena as long waves on the continental shelf.

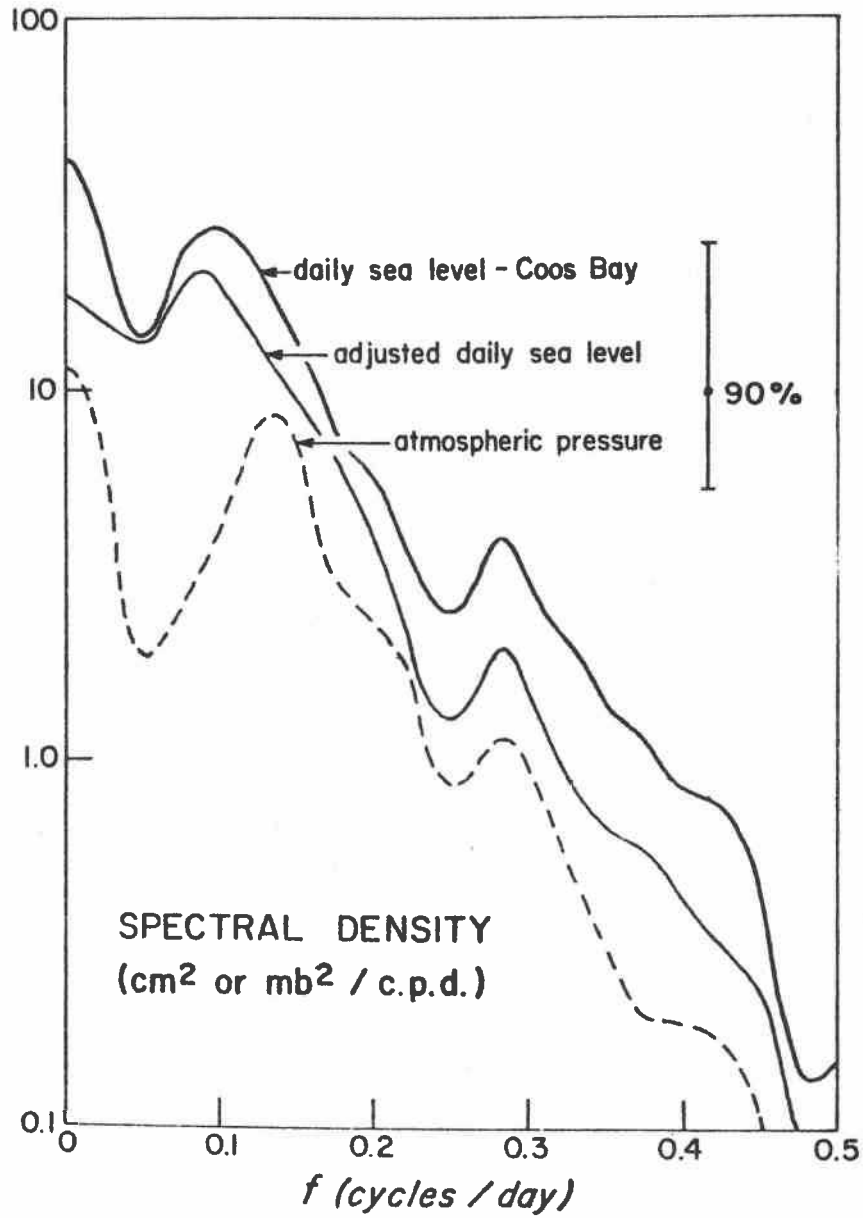
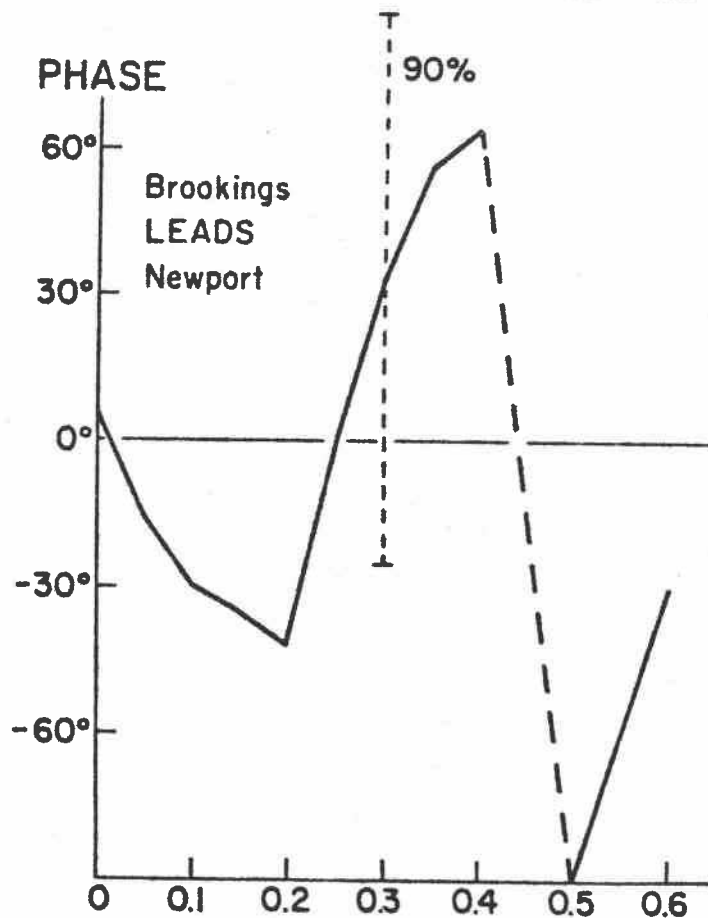
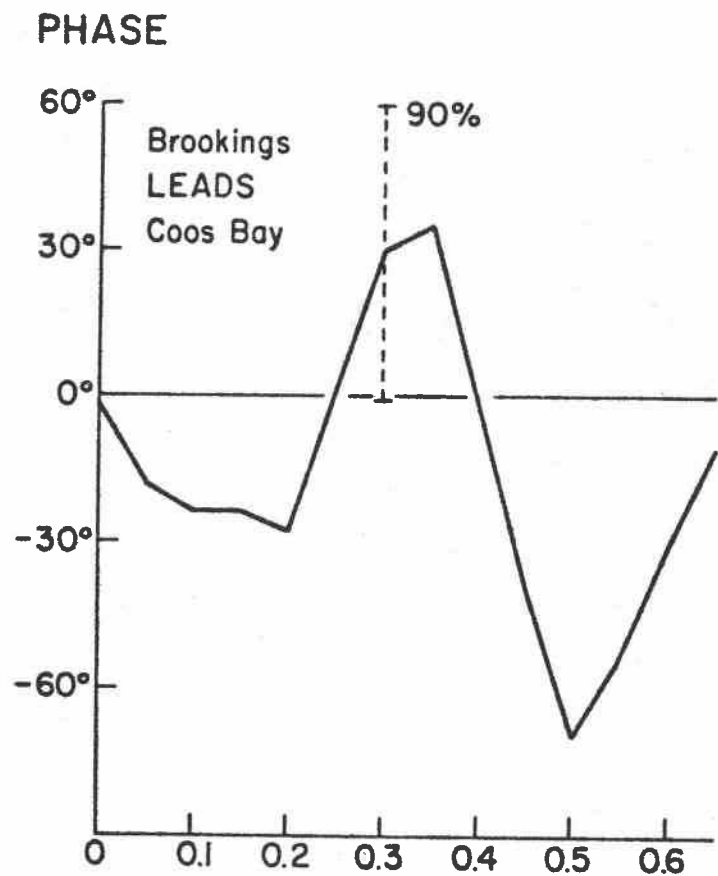
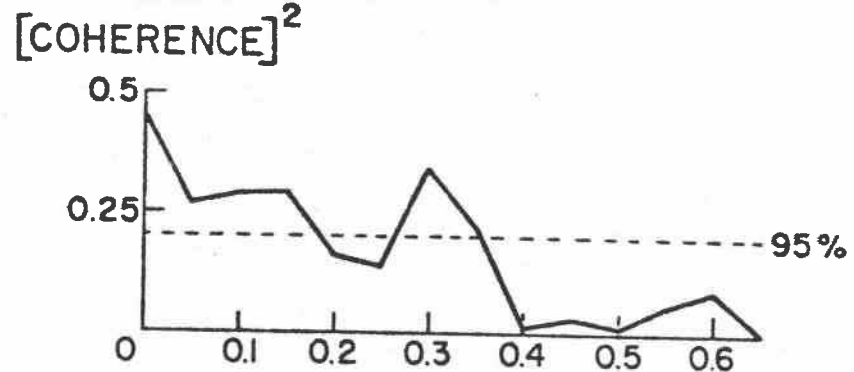
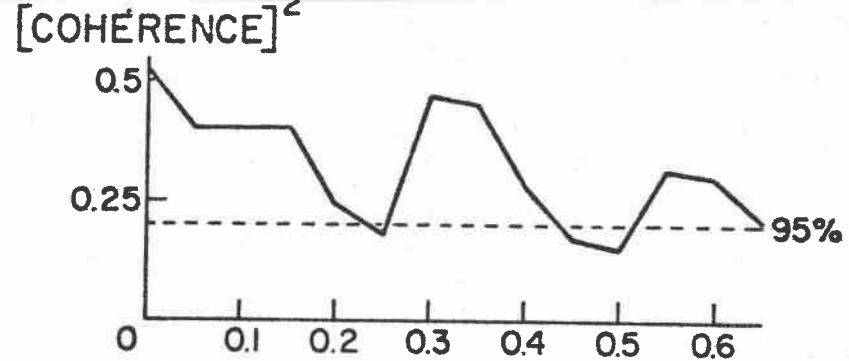


Figure 6. Energy spectrum for summer sea level.



FREQUENCY (cycles / day)

Figure 7. Coherence squared and phase at tide stations along the Oregon coast.

### Upwelling Along the Southeast Arabian Coast and the Monsoons - Smith, Bottero

The horizontal and vertical fields of motion along the southeast Arabian coast during the monsoons are being studied. Under the assumption that the horizontal motion is composed of a geostrophic flow prescribed by (1) the slope of the sea surface and the density distribution, and by (2) an Ekman flow in the surface layer, both the horizontal and vertical fields of motion along the southeast Arabian coast during the monsoons are computed. The NODC has supplied us with all Arabian Sea data on magnetic tape, and computer programs are being written by us for this study. The topography of the sea surface, necessary for computing the absolute transports, is found by the method Wyrтки used in his study of the Peru Current upwelling region. This method equivalently defines levels of no motion. The levels found by this method are compared with those determined by Defant's method.

Preliminary results found by using data from the RRS DISCOVERY cruise during the southwest monsoon of 1963 show upwelling to occur along some 1000 km of the southeast Arabian coast. The upwelling may amount to  $10 \times 10^6 \text{ m}^3/\text{sec}$  along the 1000 km. The level of no motion in the southern part of the region is between 900 and 1000 db. Similar results were found by using methods by Wyrтки and Defant.

### Hydrological Optics - Beardsley, Carder, Tucker, Zaneveld

To better relate the optical properties of the coastal waters off Oregon to physical and biological processes in the ocean, we have attempted to integrate our studies into the research programs of specialists in these areas. In particular, the base line study of the optical properties has been run concurrently with the investigation of coastal upwelling being carried out by Drs. Pattullo and Smith. Laboratory measurements of the optical signatures of cultured species provided by Dr. Curl have been made, and the results will be used in an attempt to locate these species in the ocean by using optical means.

The instrument development program is progressing as scheduled. The 3-meter optical bench for testing and calibrating photo detectors is complete, and the components of the in situ spectrophotometer have been constructed and individually tested. The system should be ready for ocean testing by mid summer

The Brice-Phoenix scattering photometer has been adapted for use with laser light, and measurements now in progress should indicate if the highly coherent red light from the laser scatters as predicted.

A contract has been signed with NOTS, Pasadena, to provide information on the optical transfer function of seawater. After two months of work, we have developed and debugged a satisfactory computer model of the transfer process, and we are now beginning the production phase of a parametric study of the dependence of the transfer function on the optical properties.

#### Boundary Kinematics - Beardsley, Earle, Plank

In an effort to better delineate the geometry of the internal structure of wind waves, two stable platforms have been assembled and tested at sea. The first, a 30-meter wooden staff, was used as an untethered wave pole and was successfully launched and recovered in seas running to 18 feet. This pole is presently being instrumented to measure, electronically, wave height and wave velocity at different depths. The second stable platform is a small toroid used in a subsurface taut-moored configuration, with a pressure transducer attached to the toroid. During the initial test, the transducer was attached to the ship with conducting cable. Work in progress will substitute a radio link for the cable and allow us to set several buoys to determine the directional wave energy spectrum.

#### Hydrography of Oregon Waters - Wyatt, Pattullo, Still, Barstow

Monthly hydrographic cruises were continued off Oregon with particular emphasis placed on the Newport line. Stations from 5 to 165 miles west of Newport were monitored to determine the salinity, temperature, oxygen, and phosphate content of the seawater. Biological collections were taken with vertical meter net trawls and midwater meter nets. Cruise dates and samples taken are summarized in Table I.

Table I. Samples taken at 5, 15, 25, 35, 45, 65, 85, 105, 125, 145, 165 miles west of Newport.

Cruise Dates	Nansen Casts	S ‰	Oxy.	Phos.	Other Chemistry	IKMW Trawl	Vert. meter net tow	BT Casts
Oct. 31 to Nov. 6	29	X	X	X		2	3	324
Nov. 28 to Nov. 30	11	X	X	X	pH alkalinity			46
Jan. 13 to Jan. 16	12	X	X	X		11	7	59
Feb. 20 to Feb. 24	22	X	X			4		155

## GEOLOGICAL OCEANOGRAPHY

### Coastal Areas

#### Sedimentation - Kulm, Spigai

The data from the heavy mineral investigation of the coastal rivers of Oregon and northern California have been reduced, and a report is being prepared for publication. These data are being used in conjunction with heavy mineral data from deep sea sands to determine the continental sources of these sands and the directions of sediment transport.

A petrographic examination was made of the heavy mineral fraction of beach sands from five selected localities on the Oregon coast. Of the more than 30 mineral species identified, the following major groups were noted to be the most prominent: hornblende, clinopyroxene, orthopyroxene, actinolite (tremolite), garnet, and opaque minerals. Actinolite and blue-green hornblende are of a high percentage in the southern samples, particularly south of Cape Sebastian, but they decrease markedly in the northern samples. Conversely, clinopyroxenes, particularly augite, show high percentage in the northern samples from Arch Cape and Otter Rock, but decrease in percentage in the southern samples. The garnet group is most prominent off central and northern Oregon. The heavy mineral suites of the beaches reflect the source rocks in the nearby drainage systems. The high percentages of augite off northern and central Oregon reflect the dominance of basic igneous rocks in these drainage systems. The actinolite, blue-green hornblende association off southern Oregon reflects a predominantly metamorphic rock source in this area.

### Continental Margin

#### Shelf Sedimentation - Kulm, Fowler, Chambers

The investigation of the sediments on the continental shelf off Oregon is continuing from Cape Blanco to the Oregon-California border. Eighty-seven samples previously collected on two-mile grid centers between Cape Blanco and the vicinity of the Rogue River are being studied for texture and composition. A map showing the various sediment types has been made for this area; it is an extension of the map covering the area from the Columbia River to Cape Blanco. The rather narrow belt of sand that was found to exist from the Umpqua River to Cape Blanco continues on past the Rogue River. The sediment pattern of the shelf off the mouth of the Rogue River is rather complex and is similar to that which occurs off the Umpqua River (Figure 1).

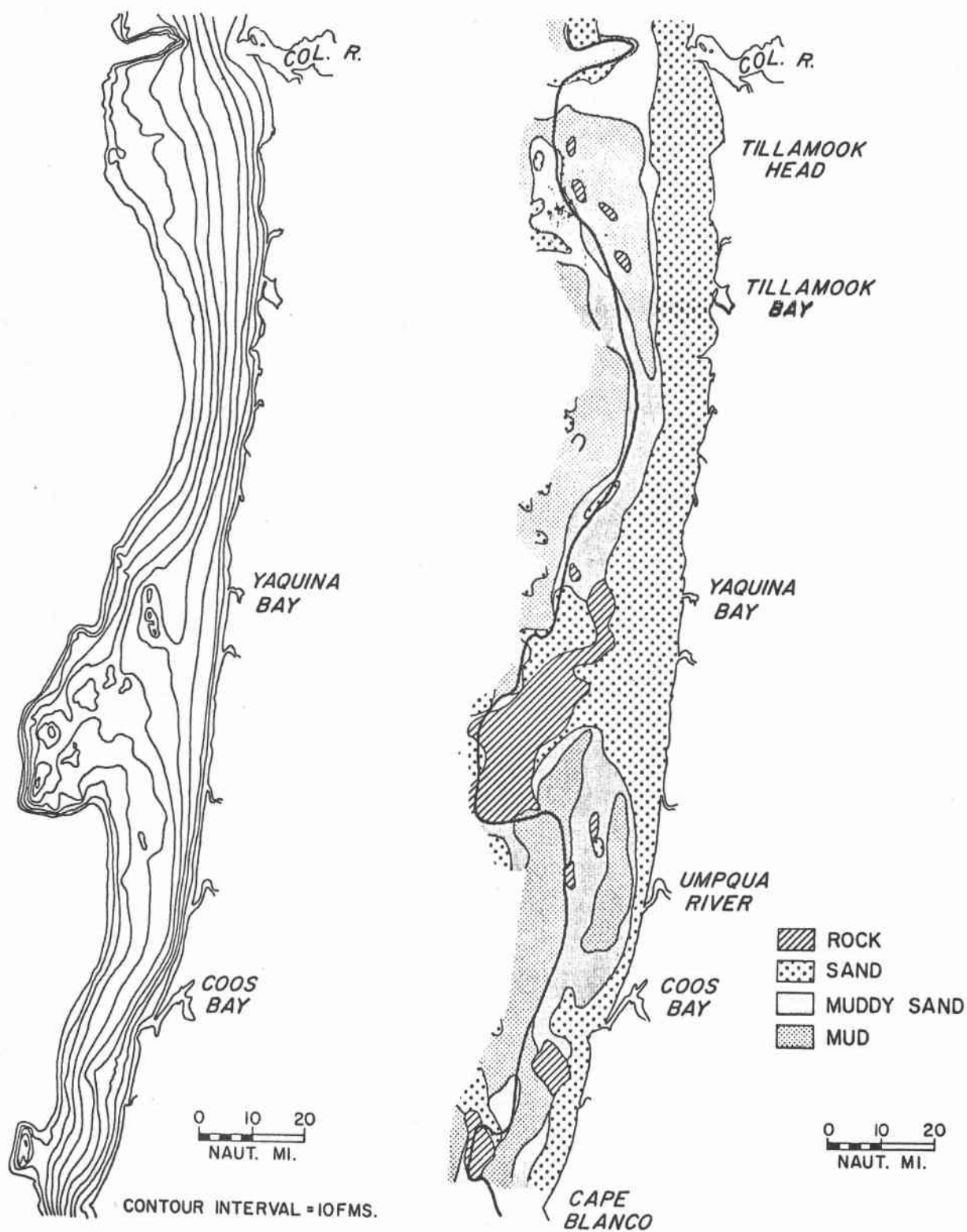


Figure 1. Bathymetry and distribution of sediment types for part of the Oregon continental shelf.

The sands that occur between Cape Blanco and the vicinity of the Rogue River on the continental shelf are currently being investigated for their heavy mineral content. These deposits have a higher heavy mineral percentage than most deposits found elsewhere along the Oregon coast.

Through the financial support of the National Science Foundation, a deep-sea photographic system (E G and G) has been purchased for photographic studies of the continental shelf, slope, and deep-sea areas. The first sea trials with the camera system were made at two stations on the continental shelf off northern Oregon 24 and 19 kilometers from shore in water depths of 160 and 142 meters respectively. About 50 bottom photographs were obtained during the trial runs and showed that there is an abundance of benthonic organisms at this depth. Photographs were taken in an area where shrimp are fished commercially; many shrimp were evident in the photographs. Substantial micro-relief in several of the close-up photographs indicates that sediment reworking by benthic organisms is quite extensive.

We plan to make detailed surveys of selected localities of the Oregon continental shelf with the camera system. Such features as current ripple marks and other primary structures that delineate current movement should be easily recognizable.

#### Astoria Canyon - Byrne, Carlson

A doctoral dissertation on the marine geology of the Astoria Canyon is nearing completion. The characteristics of the core and dredge samples studied include textural parameters, sand fraction components, light and heavy minerals, and displaced foraminifers. The sediments within and adjacent to Astoria Canyon grade from predominantly terrigenous at the upper end to chiefly biogenous constituents in the coarse fraction at the lower end. The number and thickness of sand and silt layers increase with depth in the cores. The coordinated study of Astoria Fan and Canyon indicate that Astoria Canyon was more important as an avenue of sediment transport during the Pleistocene than it is today. All available geophysical and geological data are being studied to formulate a hypothesis for the origin of the canyon.

#### Mineralogy of Silts - Kulm, Deffeyes, Allen

The study of the mineralogy of silts is continuing. Procedures are being developed to obtain optimal information from silts by various x-ray diffraction techniques. The silt-sized fractions of the samples being investigated are separated into ten micron-sized increments by settling



techniques. Light and heavy mineral separates of each increment are then taken by heavy liquid methods. Further differentiating of each fraction is effected by magnetic separations. Unoriented samples are x-rayed by using a spin-holder.

### Deep Sea

#### Astoria Fan - Byrne, Kulm, Nelson

Astoria Fan has received the bulk of its sediment from turbidity-current flows derived from the adjacent continental margin off Oregon. The mineralogical composition of the sediments from the Canyon and Fan is identical to that of the Columbia River, indicating that the Columbia is a major source of sediment and Astoria Canyon the main avenue of dispersal. Both Canyon and Fan deposits contain varying percentages of volcanic ash. On Astoria Fan, the ash is found generally as two closely-spaced layers in the top one meter of the piston cores; the layering is not as apparent in cores from the axis of the Canyon. The volcanic ash is found only on the upper and middle parts of the Fan (out to 60 km), but it occurs throughout the length of the sampled portion of Astoria Channel (120 km). Shallow-water foraminifera and plant debris are found in the volcanic ash; this suggests that the ash was transported and deposited by turbidity currents. These ash layers are tentatively correlated with the Mt. Mazama ash fall on the continent (dated 6600 years B. P.). The stratigraphic position of the deep-sea ash layers, midway between the top of the last glacial stage and the surface, leads us to believe that the ash was carried to the sea floor shortly after the Mt. Mazama eruption. With this assumption, and by using the ash layers as a dating horizon, the minimum rates of sedimentation have been calculated for Astoria Fan and Channel. Rates on the Fan are about 2 to 15 cm per thousand years; those in the Channel are about 10 to 30 cm per thousand years.

A very interesting fact is that few large turbidity-current flows have occurred on Astoria Fan for the past several thousand years. The almost complete lack of sand-sized material above the ash layers suggests the absence of large-scale flows but does not preclude the possibility of small-scale flows of silt and clay. Whether the last rise in sea level during post-glacial time or the hydrographic system of the Columbia River estuary, or both, are responsible for the present low rates of sedimentation is a subject for continued study.

### Cascadia Abyssal Plain (Cascadia Basin) - Kulm, Fowler, Duncan, Griggs

The sediments of Cascadia Channel are similar to those found in Astoria Channel and also contain significant amounts of volcanic ash (believed to be Mt. Mazama). Cyclic depositional units consisting of alternating sequences of turbidity-current and pelagic-sediment layers are recognized over 390 km of the channel. Piston cores taken south of 45°N latitude, where the channel turns southward, consist of coarse silts and clays. North of 45°N the sediments in the channel range in grain size from gravels to clay. With one exception, only postglacial sediments have been recognized in the cores taken from the axis of the channel. Radiocarbon dates of 4650 and 9670 years B.P. have been obtained in two channel cores.

Tectonic movements are implied along the course of Cascadia Channel in the vicinity of Cascadia Gap in the Blanco Fracture Zone. Based on detailed soundings in this area we have mapped a depression 110 meters in depth along the course of the channel. This depression or basin occurs where the channel is offset approximately 6 km in a north-south direction (Figure 2). The turbidity-current deposits in the axis of the channel, both upchannel and downchannel of the depression, contain substantial percentages of volcanic ash which have been correlated with the Mt. Mazama ash on the continent as described previously. Since the deposits containing ash are known to be younger than 6600 years, it is reasonable to infer that this graben-like structure formed during the last few thousand years. A nine-meter piston core taken in the depression reveals only two turbidite cycles, each about 4-1/2 meters thick, whereas normal axial turbidity-current units are usually less than one meter thick. It is evident that the depression is functioning as a sediment trap and has temporarily cut off the flow of sediment to Tufts Abyssal Plain to the west.

### Foraminiferal Ecology - Fowler, Boettcher

The study of shelf foraminifers from the area between Cape Arago and the Siuslaw River has been completed and a final report is in preparation. Faunas off the Oregon-California border (42°N) are presently being examined. Preliminary results indicate trends consistent with those reported earlier for the area to the north.

### Foraminiferal Ecology of Yaquina Bay - Fowler, Manske, Allen

Thirty additional samples have been collected in Yaquina Bay bringing the total to 431. Two hundred ninety-three have been analyzed for their foraminiferal faunas. Summer and winter spatial surveys are being treated statistically to determine the seasonal changes in both species associations

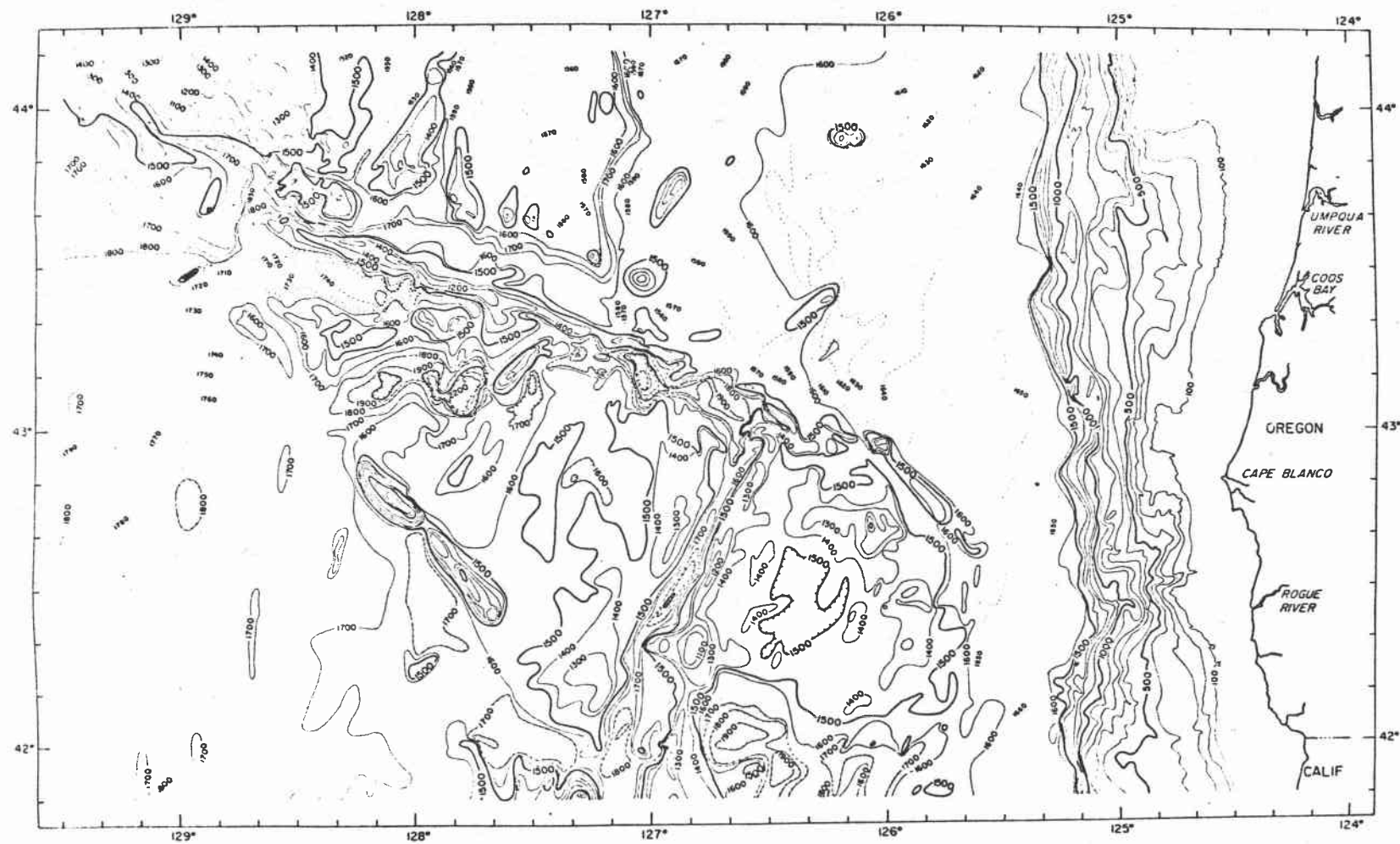


Figure 2. Bathymetry of the eastern portion of the Blanco fracture zone and vicinity. Contours are in fathoms.

and index of affinity between stations. The Fager-McConnaughey method of determining correlation coefficients is being used to define species associations. This method is based on the number of occurrences and joint occurrences of all possible species pairs identified in the samples. The Sanders method of comparing all possible sample pairs is being used to determine the index of affinity between stations. This index is a reflection of the species composition and their relative abundance in each paired comparison; it attaches a numerical value to the similarity of faunas between stations. A "trellis diagram" is employed in both analyses. The described methods are being separately applied to the living and total faunal suites.

Preliminary studies of tide pool foraminiferal faunas at Yaquina Head indicate fewer species present than have been reported from other tide pools along the Oregon coast. In the area studied species of Elphidium comprise 83 to 95% of the fauna. Elphidium microgranulosum appears with an average frequency of 80%. From 5 to 18% of the specimens observed were living at the time of collection. Most forms probably live on attached vegetation.

A distinct size grading of displaced benthic foraminifers has been noted within turbidity-current layers of Cascadia deep-sea channel. Elphidium incertum is the dominant form in basal layers whereas Buliminella elegans and Eggerella advena predominate in upper layers.

Work is continuing on the faunal stratigraphy of the deep-sea sedimentary record. Approximately 1500 samples at 10 cm intervals from 38 cores have been studied. Results to date indicate the presence of five radiolarian-rich intervals separated by four intervals of planktonic foraminifers in the deep-sea stratigraphic record of the last 30,000 to 40,000 years off Oregon.

A well-defined interval varying in thickness from 2 cm to more than 900 cm at the top of each core is represented by 50 to nearly 100% radiolarians (with 100% equal to the sum of radiolarian and planktonic foraminifers) (Figure 3). This interval is followed in at least 21 cores by one containing almost 100% planktonic foraminifers. The stratigraphically highest transition from a dominance of radiolarians to that of planktonic foraminifers has been dated between 9,600 B.P. and 15,200 B.P. Our present findings confirm the earlier opinion that this faunal transition represents a change from glacial to postglacial climatic conditions. The rather wide range in dates apparently represents a long transitional period from glacial to postglacial conditions. This transition zone is being studied in long piston cores from near the base of the continental margin and in deep-sea channels where an expanded scale is made possible by high rates of sedimentation.

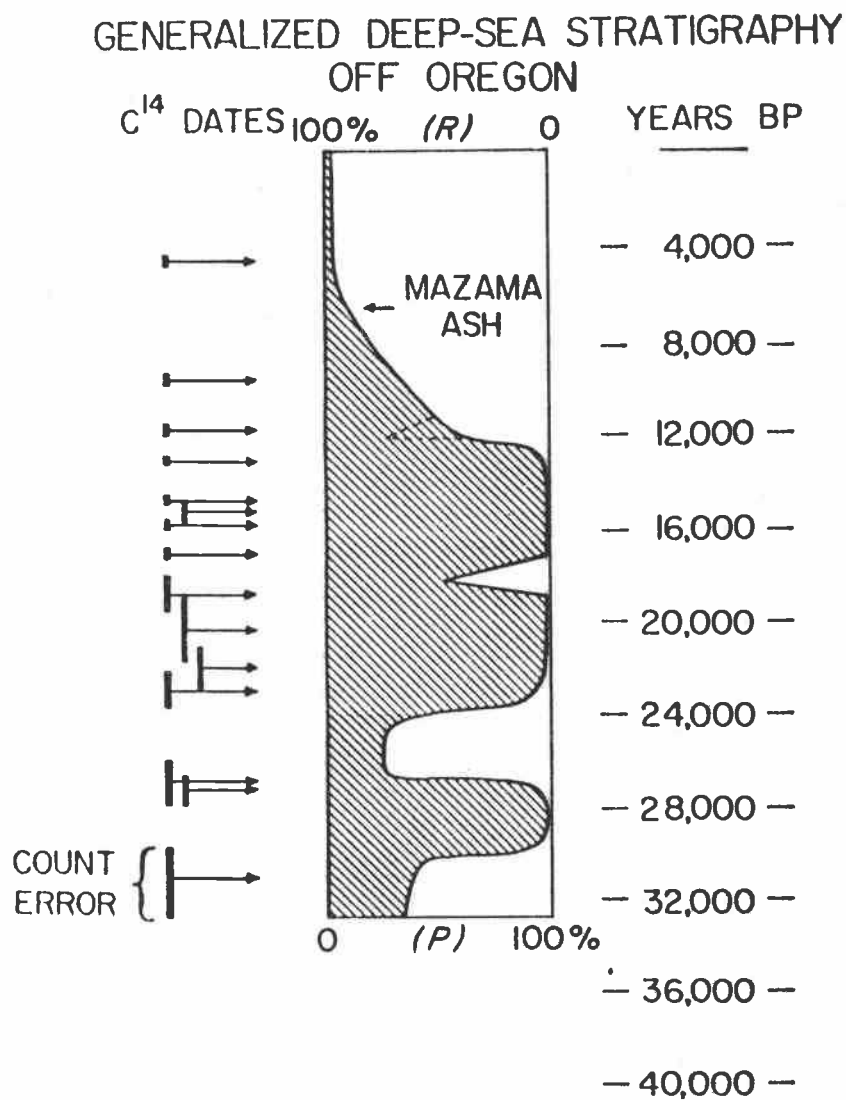


Figure 3. Trends in the relative abundance of radiolarians (R) and planktonic foraminifers (P) in the deep-sea sediment record off Oregon. The cross-hatched area represents the relative abundance of radiolarians expressed as the percent of the total radiolarians and planktonic foraminifers.

Three to possibly four other, less well defined, relatively radiolarian-rich intervals are recognized (Figure 3). The youngest of these intervals, found in 14 cores, is dated from approximately 11,000 to 12,000 years B.P.; the third interval, found in 7 cores, covers a period between 18,000 years and 19,000 years B.P. Results from three cores suggest a fourth radiolarian-rich interval occurring from 24,000 to 27,000 years B.P. In one core, the oldest radiolarian-rich interval ends approximately 30,000 years B.P. and extends back to an undertermined age.

Very preliminary studies indicate that trends in the species composition and coiling direction of planktonic foraminifers reflect paleoclimates in a much more subtle way. There is some indication that Globigerina pachyderma is present with greatest average frequency in the intervals influenced by relatively cold climates. Globigerina pachyderma is represented by right coiling forms about 40% of the time in the topmost radiolarian-rich interval. Below this the average is only about 5%; however, the highest percentages (up to 5%) occur in the radiolarian-rich intervals.

#### Gorda Ridge Mapping Program - Deffeyes, Russell, Heinrichs, Fowler, Kulm

Investigations on the axial valley of the Gorda Ridge were carried out on two cruises of the R/V YAQUINA in October 1966 and January 1967. During the first cruise, we mapped a 500-square mile area with PDR and magnetometer tracks one-half mile apart. Film positives of the PDR traces were stacked to make a model of the axial valley. The most spectacular features of the model are steps on the inward facing walls of the axial valley. These steps, some are continuous throughout the entire 25-mile length of the surveyed area, resemble the terrain produced by normal faulting on land.

During the second cruise, rocks were dredged from two lines across the surveyed area. To record the exact depths from which rocks were dredged, we attached a rugged pressure-time recorder to the rock dredge. The recorder, a standard petroleum industry design, performed well even under the accelerations (4 to 15 g) associated with the dredge.

The majority of the rocks recovered were basalts. However, we were quite surprised to recover weakly consolidated sandstones and siltstones from the walls of the axial valley. A preliminary examination of the foraminifers from these sedimentary rocks indicates that their age is Recent, Pleistocene or latest Pliocene; a closer age assignment is not possible at this time.

The presence of some shallow-water benthic foraminifers and the presence of a heavy mineral suite typical of the Klamath Mountains drainage suggest that the rocks are turbidity-current deposits which probably entered the axial valley from the open southern end. A corollary to this tentative hypothesis is that sedimentary deposits from the floor of the axial valley are being uplifted along the valley walls. Reconciliation of the apparent morphologic evidence of normal faulting and the evidence for uplift will require some readjustment of ideas about the genesis of the axial valley.

## GEOPHYSICAL OCEANOGRAPHY

### Marine Gravity - Couch, Gemperle, Banks, Skorpen

Preliminary free air gravity maps have been prepared from approximately 7200 gravity stations west of British Columbia and Washington. Isostatic anomalies are being determined for 100 selected stations along the Inside Passage of Alaska and British Columbia.

Geophysical measurements made during the YALOC Cruise of 1966 have been reduced. A free air gravity map has been prepared from approximately 500 gravity stations north of Hawaii. The February 1966 Mendocino Escarpment free air gravity anomaly map has been extended westward by 250 gravity stations. Gravity measurements at 600 stations across the Aleutian Ridge and Trench near Adak have been reduced to a free air anomaly map. Total magnetic field measurements have been compiled for the Mendocino, Hawaii, and Adak areas and preliminary magnetic maps have been drawn of the Mendocino and Adak areas.

### Earthquake Seismology - French, Gallagher

The World-Wide Seismic Station at Corvallis and the satellite station at Klamath Falls, Oregon, have been operated continuously during this period.

The investigations of earthquake focal depths and source mechanisms have been continued in extended studies of crustal and subcrustal structures in the Pacific Northwest states.

### Land Gravity - Heinrichs, Thiruvathukal

From 1962 to 1966, a broad gravity program has been underway which consists of establishing gravity base station control and compiling data for more than 8000 gravity measurements made in Oregon. This project is now being completed.

Free air and Bouguer anomaly maps of Oregon have been constructed and are being published by the Oregon State Department of Geology and Mineral Industries (Scale: 1:500,000). Several distinctive features of the Bouguer gravity map are (1) a generally decreasing gravity field toward the southeast, probably related to major variations in regional geology such as an increasing crustal thickness in the southeastern part of Oregon; (2) a steep gravity gradient about 50 miles east of the coast indicating a major structural feature; (3) a lack of expression for the Cascade Mountain Range; and (4) isolated gravity highs and lows in the area of Plio-Pleistocene volcanism.



The final analysis of the gravity anomalies and their interpretation in terms of both regional and local geology of the state is being completed. The data are also being used in the investigation of different techniques for determining regional and residual anomalies. This work is still under-way.

#### Magnetics - Heinrichs, Bales, Emilia, McKnight

A regional study of the magnetic field off the coasts of Washington, Oregon, and northern California is continuing. One of the purposes of this study is to extend measurements in to the coast both to determine whether the anomalous north-south magnetic lineation, found offshore, continues to localized magnetic anomalies and also to determine their depth, bottom expression, and relationships with the continental mass and shelf. Total field results for measurements through 1965 have been published and anomaly maps and interpretation are being published.

A detailed magnetic survey of the axial valley of Gorda Ridge was made in December 1966. Forty-five east-west crossings were made in the area from  $41^{\circ} 10' N$  to  $41^{\circ} 30' N$  and from  $127^{\circ} 10' W$  to  $127^{\circ} 40' W$ . Three north-south tie lines completed the survey. These data have been reduced and are now being interpreted.

The remanent magnetization properties of a suite of Recent High Cascade lava flows were determined. The results are being analyzed for information on the secular variation of the recent paleomagnetic field and a formal report is in progress. An improved spinner magnetometer has been designed and the mechanical part of the system is being constructed.

#### Theoretical Studies - Bodvarsson, Maloof, Emilia, Vossler

The study of direct interpretation methods is continuing. Work in progress includes problems in electromagnetic scattering theory and potential field theory with application to magnetic anomalies.

The research on potential fields and the filtering of potential field data were continued, along with the theoretical study of two-phase critical flows in collaboration with Dr. D. S. Ryley at the University of Liverpool, England.

Eddy diffusion models for the transport of heat above the ocean-bottom interface are being studied with regard to the influence of terrestrial heat flow anomalies on the temperature microstructure in the ocean.

The various modes of heat transport in the crust and mantle below the ocean floor are being studied with regard to the interpretation of ocean floor heat flow anomalies.

Ocean Floor Temperature Studies - Bodvarsson, Mesecar, Shih

Figure 1 shows the location of four thermoprobe stations made on the abyssal plain area off Depoe Bay, Oregon. Seven water and sediment temperatures were recorded about the ocean-bottom interface. A sample of the temperatures from these stations is shown in Figure 2.

Thermoprobe stations have also been made on the continental shelf, down the slope, and out into the abyssal plain area off the coast of Oregon. Continuous records of water and sediment temperatures on the shelf were made for a 24-hour period. At the same station, seven-day records were made where the temperature sampling was hourly.

Thermoprobe stations down the slope were selected for their geographic and bathymetric spacing westward. Short term recordings were made at each of these stations.

Recordings from these stations are now being reduced.

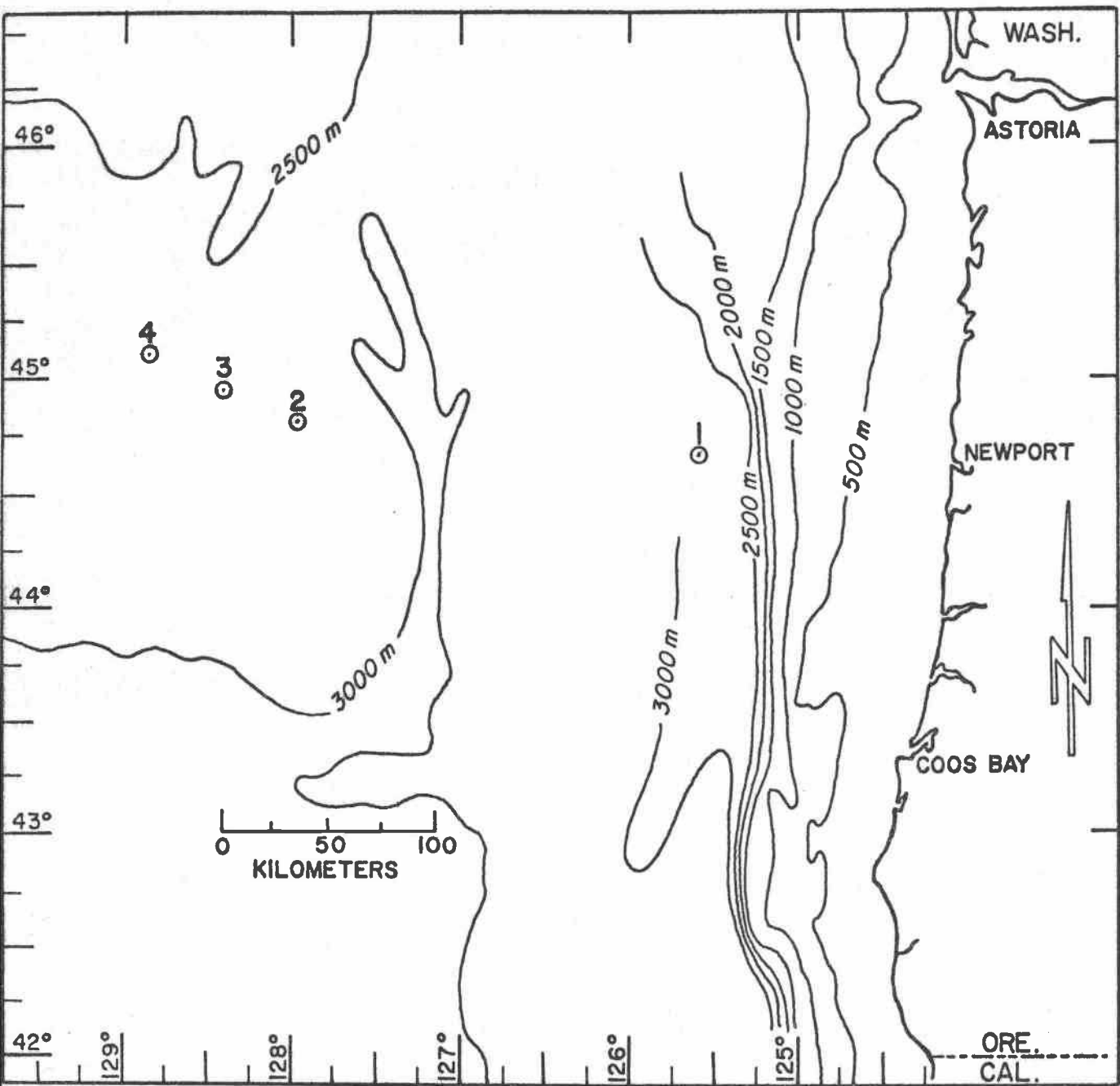


Figure 1. Four thermoprobe stations off the Oregon coast.

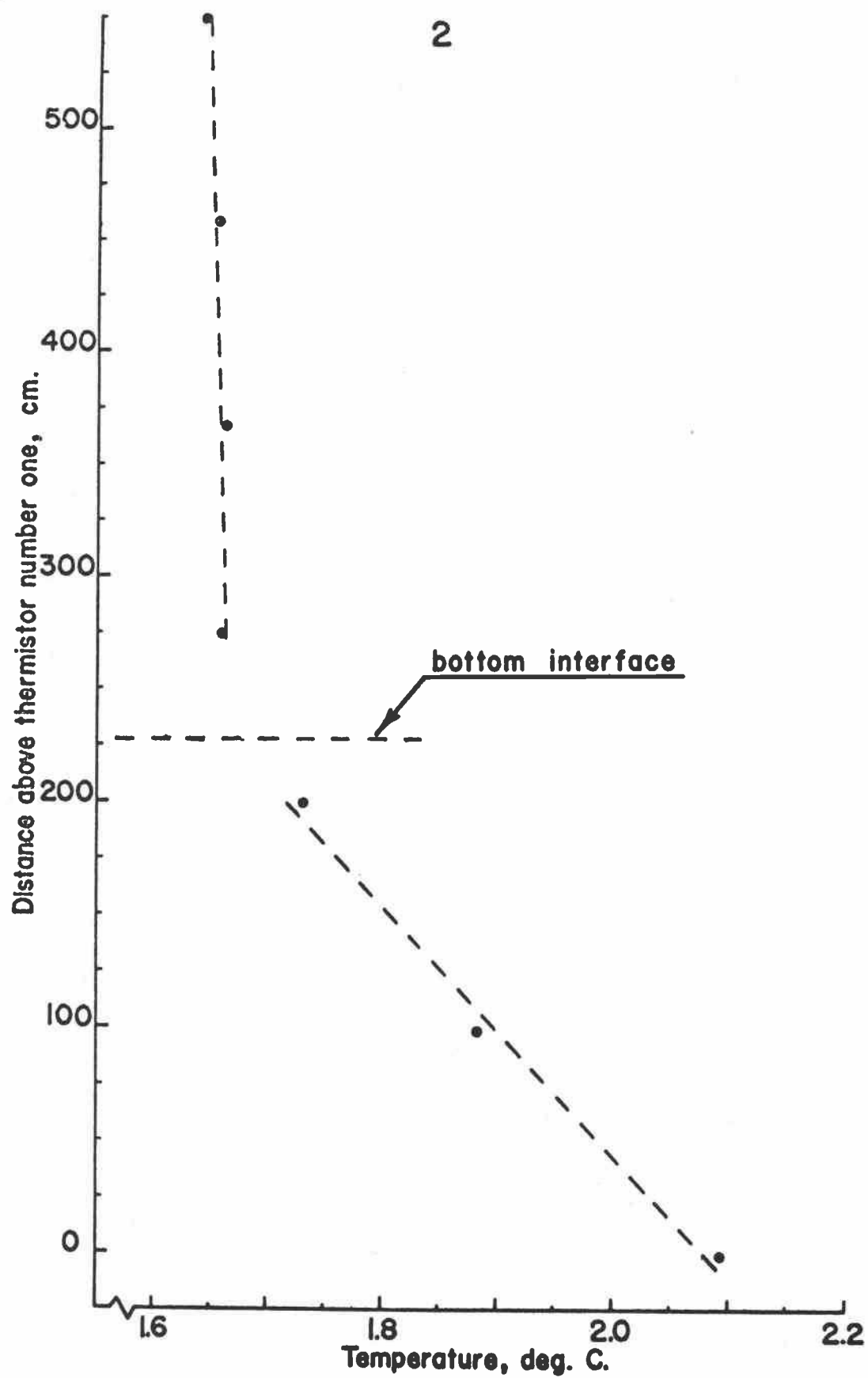


Figure 2. Temperature regime of Station 2.

## CHEMICAL OCEANOGRAPHY

### Improvement of Shipboard Technique - Park, Gordon, Bradford, Cissell

**Nutrients** - In addition to phosphate, nitrate, and silicate analysis, iron as a plant nutrient will be determined by the Technicon Autoanalyzer. Mr. Cissell has begun to assemble a set-up for the nitrate determination by the cadmium-copper reduction technique of Wood et al.<sup>1</sup>

**Cations** - Mr. Bradford has begun to test a calcium electrode for the determination of dissolved calcium in Columbia River estuarine waters. Other cation electrodes will also be employed.

**Oxygen** - Mr. Gordon has been studying the theoretical feasibility of coulometric technique to determine dissolved oxygen. Dr. Freund, Department of Chemistry, Oregon State University, is collaborating on this effort.

**Carbon dioxide** - Infra-red CO<sub>2</sub> analyzer will be used to determine both total CO<sub>2</sub> and undissociated CO<sub>2</sub> in seawater. A simple CO<sub>2</sub> equilibrater (air-water) is being designed.

### Offshore Chemistry - Park, Kujala, Catalfomo, Webster,\* Reed\*

Seasonal distribution of nutrient matter (phosphate, silicate, and nitrate) off Oregon for 1966 has been completed. The nutrient data are being compared with the oxygen and carbon dioxide data to show the nutrient-gas relationship off the coast.

Total CO<sub>2</sub> data obtained by chromatographic determination in the deep water (71,000 m) off Oregon are being analyzed in order to understand the CO<sub>2</sub> system in the deep ocean.

### Estuarine Chemistry - Park, Kujala, Catalfomo, Webster,\* Reed\*

A study of the nutrient and alkalinity budget of the Columbia River for 1966 has been completed. Figure 1 shows the chemical distribution of the river water at Astoria in 1966 (at salinity of 0‰). Nutrient minima during summer months indicate intensive photosynthesis occurring in the flowing water.

<sup>1</sup>Wood, E. D., F. A. J. Armstrong, and F. A. Richards. 1967. Determination of nitrate in seawater by cadmium-copper reduction to nitrate. J. Mar. Biol. Assoc., United Kingdom, 47(1):23-31.

\*Pacific Northwest Water Laboratory

## Astoria

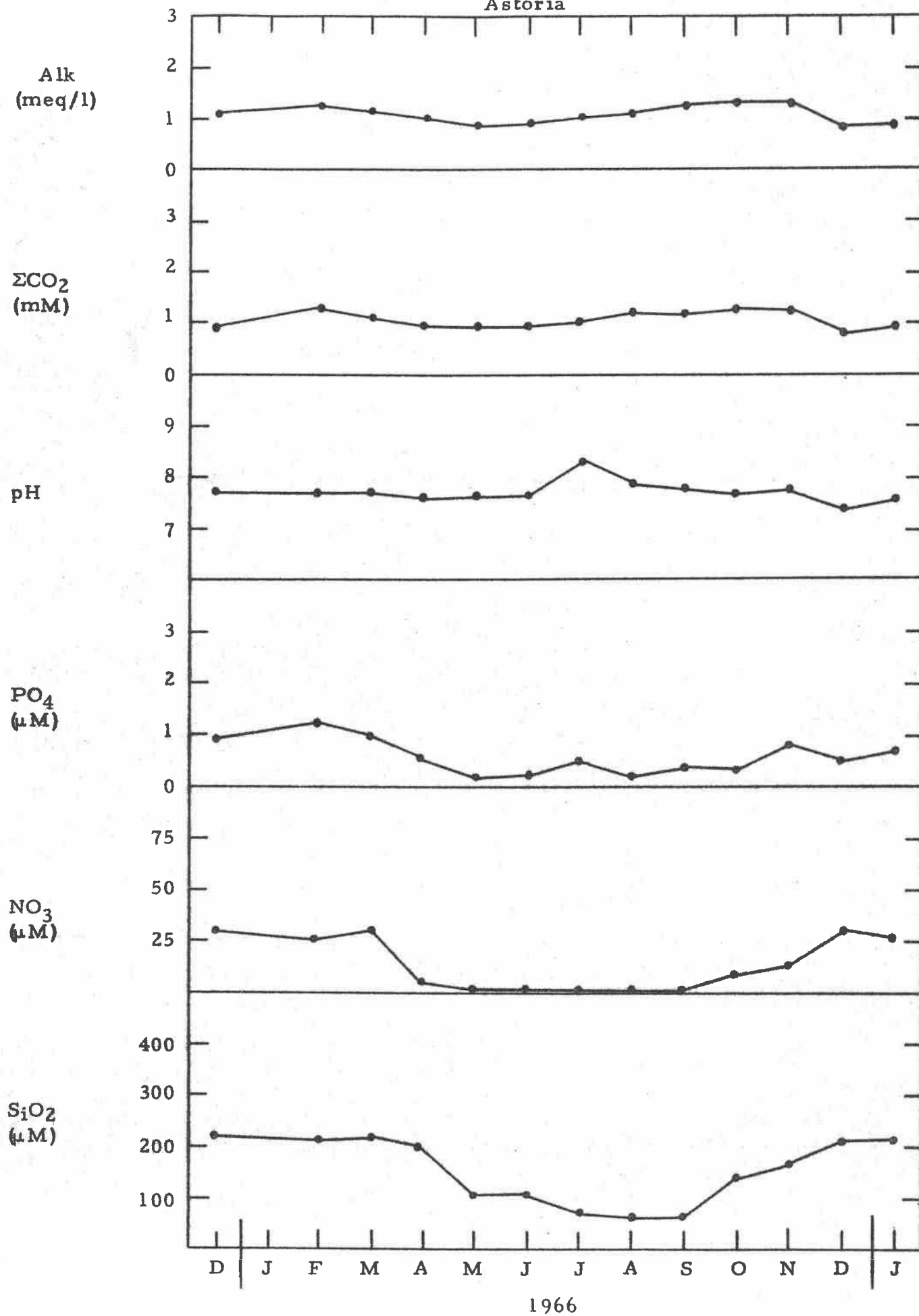


Figure 1. Chemical distribution of seawater off Astoria, Oregon

### Carbonic and Boric Acids - Pytkowicz, Kester, Culberson

The determination of the apparent dissociation constants of carbonic and boric acids in seawater at pressure is being extended to temperatures below 22° C.

### Sulfate Complexes - Pytkowicz, Kester

Preliminary calibrations are being made on ion exchange electrodes which will be used to study sulfate complexes in seawater as a function of temperature and pressure.

### Calcium Carbonate - Pytkowicz

Measurements on the solubility of calcium carbonate in seawater at high pressures by using in situ electrodes were made during a recent visit of Dr. Pytkowicz to the University of Liege, Liege, Belgium. Investigations with the continued cooperation of Professor A. Distèche, University of Liege, are being carried on at Oregon State University.

## YALOC-66 Chemical Work

### Carbon Dioxide Air-Sea Anomaly - Park, Curl, Glooschenko

Surprisingly low surface  $P_{CO_2}$  (partial pressure of  $CO_2$ ) in the subtropic water during summer has been correlated with the chlorophyll a content. The  $P_{CO_2}$  minimum was at the chlorophyll a maximum. It is probable that the high chlorophyll a content is due to a recent phytoplankton bloom, which in turn lowers  $P_{CO_2}$ . Figure 2 shows the surface  $P_{CO_2}$  contours in the Pacific during summer.

### Chemical Synoptics of the YALOC-66 Cruise - Park, Erdmann, Still, Wyatt, Catalfomo, Gunnings, Neal, Panshin, Barstow, Connors

Vertical distributions of various chemical parameters are being plotted and compared with physical data.

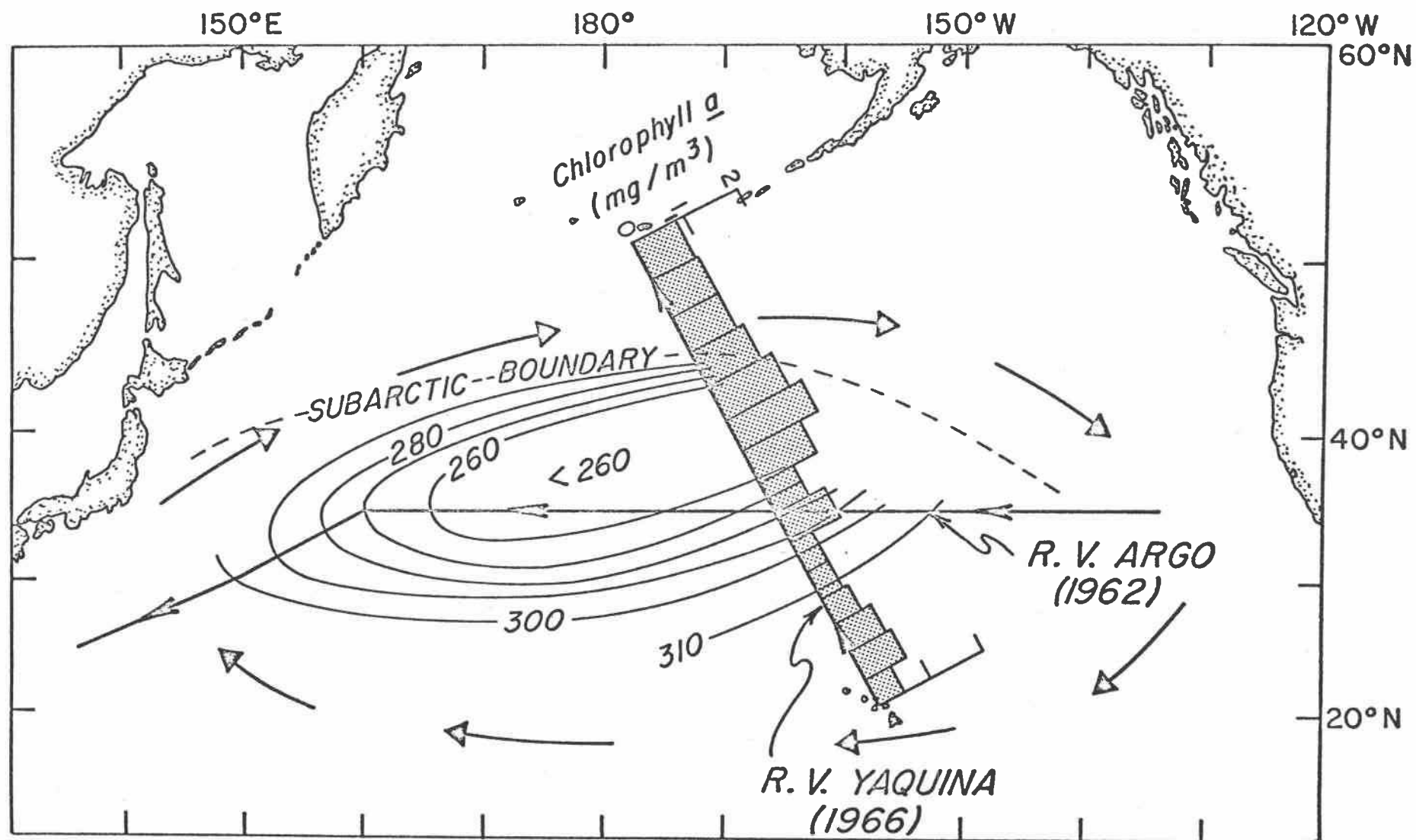


Figure 2 Surface P<sub>CO2</sub> contours in the Pacific during summer 1966.



## RADIOCHEMISTRY AND RADIOECOLOGY

Chromium-51 in Columbia River - Cutshall,\* Osterberg

We have traced radioactive chromium-51 down the Columbia River and into the Pacific Ocean. Investigations also have revealed the chemical factors influencing the partitioning of  $\text{Cr}^{51}$ , from Hanford waste, between solution and sediment.

Chromium-51, a hexavalent oxyanion when introduced into the Columbia River, remains principally in solution during its passage through the lower river and even into the Pacific Ocean. Reduction of  $\text{Cr(VI)}$  to  $\text{Cr(III)}$  apparently precedes or accompanies sorption onto iron oxides. Sediment organic matter acts both as a reducing agent, making  $\text{Cr}^{51}$  less soluble, and as a sorption substrate. Ion exchange on sediment particles is not important in retention of  $\text{Cr}^{51}$  by Columbia River sediment.

A lowered pH, large amounts of particulate organic wastes, increased temperature, and increased biological oxygen demand would all increase the rate of uptake of  $\text{Cr}^{51}$  by sediments.

Extraction of Zinc from Seawater - Buffo, Forster, Osterberg

Zinc in seawater, in the 20 ppb range, was concentrated and extracted by chelating with D. E. D. T. C. in the organic solvent M. I. B. K. at the normal pH of seawater. A back extraction into HCl provided a total concentration of 30X which allowed the detection by atomic absorption spectroscopy.

Dispersion of Columbia River Plume by Radioactivity - Frederick, Osterberg, Smith

Chromium-51, a trace radionuclide from the Hanford reactor, has been used effectively to determine the distribution pattern of the Columbia River plume at sea. The surface velocity of the ocean currents transporting the plume and the lateral eddy diffusion coefficient of the plume as it diffuses into the surrounding oceanic water have also been investigated.

Chromium-51 was first concentrated by precipitating it from 580 liters of seawater with ferric hydroxide and then detecting it with a sensitive gamma-ray spectrometer. Results indicate the plume was transported by

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\*Present address: Oak Ridge National Laboratories, Tennessee.

a southerly-flowing surface current at 12.5 cm/sec in the summer and by a northerly-flowing surface current at 11 cm/sec in the winter.

#### Iron-55 Studies - Jennings, Beasley, Kujala, Osterberg

Iron-55, which decays by electron capture and emits only a soft x-ray, has been measured in samples of Pacific Salmon from Japan and from several stations along the west coast of North America. The  $\text{Fe}^{55}$  levels are at least two to three orders of magnitude higher than gamma emitters ( $\text{Zn}^{65}$ ,  $\text{Mn}^{54}$ , and  $\text{Cs}^{137}$ ) measured in the same samples. In order that specific activities of iron can be compared among samples, the stable iron has been determined by a modified colorimetric technique using orthophenanthroline. The value of these  $\text{Fe}^{55}$  determinations enhances the knowledge of the gamma activity of the same samples.

#### Lead-210 and Polonium-210 in Marine Organisms - Beasley, Osterberg, Forster

We are attempting to define activity levels of naturally occurring radioisotopes,  $\text{Pb}^{210}$  and  $\text{Po}^{210}$ , in selected marine organisms in various trophic levels. A particular emphasis is being placed on those species which might serve as a source of food for humans.

#### Techniques of Solvent Extraction of Organic Material from Natural Waters - Cronin, Osterberg, Burger,\* Martin\*

Manual and automatic solvent extraction techniques were used to concentrate organic material from natural waters. Field and laboratory extractions were compared to determine the most probable method and best solvents for efficient concentration of organic material from estuarine water and sea water.

The large scale extraction processes utilizing extractors made from 55-gallon drums were operated both by manually moving perforated metal discs through the water and solvent for mixing and by bubbling air through the aqueous-solvent mixture. Resulting samples proved large enough for the detection of short-chain fatty acids (carbon length 1 through 10). Identification of organic constituents was by gas chromatography-mass spectroscopy. Other portions of these samples were separated by column chromatography with subsequent analysis by infrared, visible, ultraviolet, and mass spectroscopy.

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\* Battelle Northwest Laboratories, Richland, Washington.

### Radioecology of Columbia River Estuary Plankton - Haertel, Osterberg

In order that zooplankton may be radioanalyzed, methods have been devised for the separation of the zooplankton from the detritus present in the water. A monthly sampling program is being carried out in the Columbia River estuary. Samples for zooplankton content are collected at different depths and tidal stages at six stations and analyzed for species abundance, distribution, and radionuclide content. Phytoplankton samples are analyzed for standing crop, species abundance and distribution, and when possible, for radionuclide content.

We hope to correlate the findings of zooplankton abundance and phytoplankton abundance with nutrient distribution as well as radionuclide abundance.

### Columbia River Estuary Fishes - Kujala, Osterberg

Since 1963 four sampling stations in the Columbia River estuary have been sampled monthly for fishes, invertebrates, and plankton. Other parameters such as salinity, temperature, dissolved oxygen, and nutrient content have also been determined.

The fish are examined for size, age, weight, stomach contents, distribution, and population. Radioactivity is measured in muscle and bone samples of each species and age class. The activities are indicative of the pathways the artificial radionuclides take in the Columbia River.

The starry flounder population was determined by fin-clipping 4,126 fish of varying lengths and later recovering 35 fish which were less than 8 cm in length. We estimated that these flounders are on the bottom at low tide in an abundance of 2.3/ft<sup>2</sup>.

### Radionuclide Transfer through Food Web - Renfro, Osterberg, Thompson

Radioanalyses of water, sediments, plants, and animals collected from Alder Slough, a small arm of the Columbia River estuary, over a one-year period have been completed. Concurrent measurement of both radioactive and stable zinc permitted computations of the specific activity of Zn<sup>65</sup>. The temporary shutdown of the nuclear reactors at Hanford, Washington, the source of most Zn<sup>65</sup> in the Columbia River, provided an opportunity to study rates of Zn<sup>65</sup> specific activity loss in organisms. A paper detailing portions of this investigation will be read in May and presented for publication at the Second National Symposium on Radioecology.

Uptake of Radioisotopes by Amphipods - Cross,\* Osterberg, Dean,\*\* Small

Laboratory studies were conducted to determine the influence of temperature, feeding, and sediments on the uptake of  $Zn^{65}$ ,  $Ce^{144}$ ,  $Sc^{46}$ , and  $Cr^{51}$  by a new species of gammarid amphipod (Anonyx sp). Zinc-65 accumulation and elimination rates were temperature dependent, although small relative to this organism's seasonal temperature range. Labelled brine shrimp were fed to individual amphipods; transfer rates averaged 55% for  $Zn^{65}$  and less than 10% for  $Ce^{144}$  and  $Sc^{46}$  with no transfer of  $Cr^{51}$  detected. Elimination of  $Zn^{65}$  in amphipods receiving non-radioactive food were significantly greater than in unfed amphipods. Autoradiographs of  $Zn^{65}$  accumulated from water showed localization on the exoskeleton and extra-cellular spaces within muscle tissue.

Radiosensitivity Studies on Pacific Coast Mussels - Vermeere, Forster, Osterberg

Recently members of the radiochemistry group have been performing radiozinc analysis on the mussels from along the Pacific coast. The common mytilus, a second trophic level animal, is a filter feeder. Our interest is in observing an organism that will feed on these mussels. The ideal animal seems to be the common Pacific coast starfish, Pisaster ochraceus, which feeds almost entirely on the mussels. Future studies will be correlated to specific activity studies for radiozinc, and possibly other cations, as compared with the distribution of the Columbia River plume.

Effects of  $Co^{60}$  Gamma Irradiation on the Radio Sensitivity of the Brine Shrimp, Arteruina sp. - Holton, Osterberg

A series of experiments is being performed to evaluate the effects of acute doses of gamma rays, from a  $Co^{60}$  source, on brine shrimp, Arteruina sp. These experiments test laboratory populations to reproduce and to maintain stable populations.

The animals are being studied in three-liter population cultures by maintaining constant conditions and by feeding a standard amount of food daily, as well as by pair mating the shrimp. From the pair matings it is possible to calculate the intrinsic rate (r) of increase, both of the control population and of the various irradiated populations.

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\*Present address: USBCF Radioecology Laboratory, Beaufort, North Carolina.

\*\*Battelle Northwest Laboratories, Richland, Washington.

The intrinsic rate of increase is affected by relatively low doses of irradiation, but the animals are able to maintain stable and dense populations at much higher doses under laboratory conditions. However, it is possible that, under field conditions where the populations might be subjected to more stress, the lowered intrinsic rate of increase at low doses could lead to fluctuations in the population size, which in turn could lead to extinction of the population.

An incidental result of the primary study has been an evaluation of the effects of irradiation on different stages of the life cycle of the shrimp. The irradiation of animals which have reached adult size but which do not have mature reproductive glands has provided the most useful data for this series of experiments. When irradiation is great enough to eliminate reproduction, the animals' life span is increased by about 50% over the control animals.

#### Differential Uptake of Radioisotopes by Cancer Magister - Tennant, Osterberg

Cancer magister, known on the West Coast as the Dungeness crab, is a commercially important seafood. Since radioactivity in the Columbia River is well below any dangerous levels, it has been assumed that fish foods from the river are not dangerously contaminated. However, it has been shown that shellfish can concentrate stable elements thousands of times. By studying the concentration factors, we can make assumptions about permissible activity levels in the river.

We are dissecting crabs taken from Chinook Point and Buoy 10 in the Columbia River into the following parts: carapace, carapace hair, mouthparts, leg shell, leg muscle, stomach, gills, hepatopancreas, gonads, plus occasional whole fractions, i. e. tail section.

The tissues are ashed and analyzed for radioisotopes  $Zn^{65}$ ,  $Mn^{54}$ ,  $K^{40}$ , and  $Cr^{51}$ , some of which are introduced into the river water from Hanford reactors. The tissues are also analyzed for their respective stable element concentrations.

The objectives are to determine which parts of the crab take up these radioisotopes in the greatest concentrations and how the radioisotopes compare with stable isotopes from the same tissue fractions. Sampling has been on a year-round basis so that seasonal variations may be detected.

Specific Activity of Mussels by Neutron Activation - Larsen, Osterberg, Forster

Mussels along the Oregon coast are being collected and their specific activities determined. Analysis of stable zinc is being made by both atomic absorption and neutron activation (Triga reactor). The measurements of  $\text{Zn}^{65}$  are by gamma ray analysis utilizing a NaI(Tl) crystal and a multi-channel analyzer.

Vertical Distribution of Radioactivity in the Columbia River - Hanson, Forster, Osterberg

Mr. Hanson wrote his master's thesis on this research. Part of the abstract follows:

In situ salinity, turbidity and temperature were measured at discrete depths and water samples for radioanalysis were simultaneously collected in the Columbia River estuary using a specially designed instrument package.

Particulate radioactivity was concentrated by filtration and the dissolved radioactivity by evaporation or ferric oxide bulk precipitation. Radioanalysis was by gamma-ray spectrometry and data reduction by computer. Chromium-51 was mostly particulate and non-conservative. The intrusion of salt water into the estuary was seen to greatly increase the concentrations of particulate chromium-51, zinc-65 and scandium-46 near the bottom.

The fall and rise in estuarine radioactivity levels were followed during an infrequent pause in Hanford reactor operations. Changes in radioactivity levels of up to three orders of magnitude were recorded at Astoria, Oregon, some 380 miles from the reactors (Figure 1). The pause in reactor operations enabled the determination of river flow times from the reactors to Astoria. Flow times of 12 and 19 days were measured for average river discharges of 290,000 and 130,000 c.f.s., respectively.

Radioecology of Marine Animals - Percy, Eagle, Larsen, Forster, Osterberg

During the past six months we radioanalyzed 98 samples of marine organisms, including deep-sea, pelagic, and benthic fauna. Trace element analysis for zinc has been completed on 180 samples.

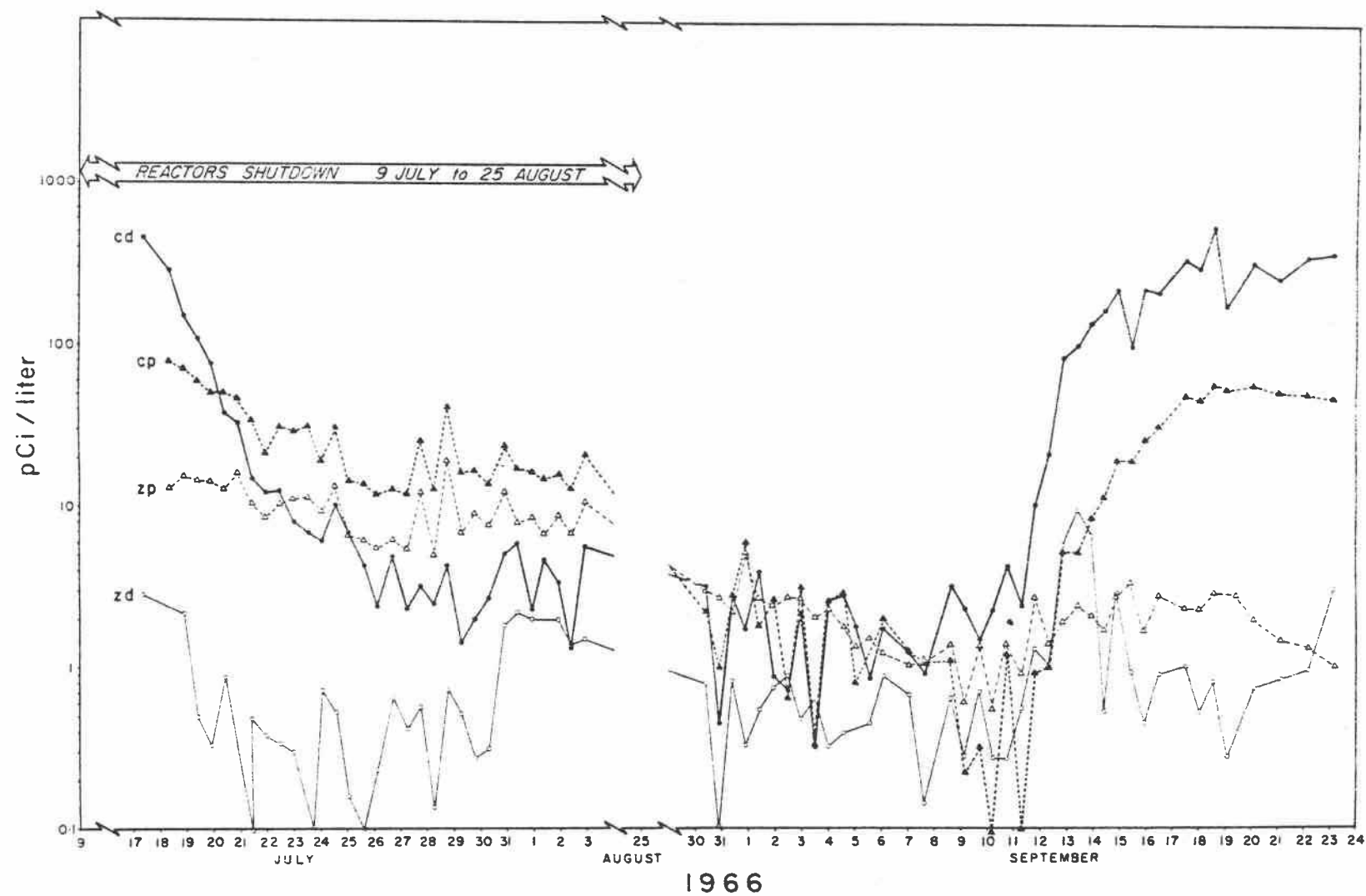


Figure 1. Radionuclide concentrations at Astoria, Oregon during pause in Hanford reactor operations.

Our analysis of  $\text{Zn}^{65}$  and  $\text{Mn}^{54}$  in albacore tuna is nearing completion. Specific activities are now being studied in benthic fishes and in pelagic animals.

Radioecology of Benthic Animals - Carey, McCauley, Paul, Stander,  
Sharpnack, Larsen, Osterberg, Forster

During this report period 173 samples, representing 50 animal species and 16 sediments off Oregon, have been radioanalyzed for gamma-splitting radionuclides. In addition, 49% of the animal samples with significant amounts of radiozinc were analyzed by atomic absorption spectrometry for total zinc content. These two types of data are now being used to compute specific activities of zinc for a more detailed analysis of the radioecology of benthic organisms. A paper summarizing these data is now in preparation.



## BIOLOGICAL OCEANOGRAPHY

### Ecology of Oceanic Animals - Percy, Laurs, Van Arsdale, Coleman

Collections of oceanic animals taken during the past six years have been examined to learn the extent and regularity of seasonal and geographic variations. Seasonal variations were apparent in the catches of the common species of squids and lantern fishes (Figure 1). Analyses of size-frequency histograms suggest that these fluctuations are related not only to recruitment of young but also to immigration of animals into the sampling area.

Seasonal variations were also correlated with ocean circulation. Several species of copepods and salps occurred inshore only during the winter when surface currents were onshore and inshore; offshore hydrographic conditions were fairly uniform. No obvious relationships were found between the percentage of Subarctic water off Oregon and the distribution of hyperiid amphipods.

During upwelling the inshore portion of the oceanic frontal layer sloped upward and intersected the surface producing a surface front. This front had an important influence on the distribution of organisms (Laurs, 1967). The standing stocks of phosphate-phosphorous, phytoplankton, herbivores, and usually primary carnivores decreased abruptly seaward of the front. During the past six months 40 one-meter net and 40 midwater trawl samples have been taken on the Newport line of stations.

Research is now in progress to estimate the growth rates of the common oceanic species of micronekton.

### Sonic Scattering Layer Studies - Donaldson, Percy

We have studied sound scattering by marine organisms off the Oregon coast and between Hawaii and the Aleutian Islands. Off Oregon some seasonal variations in the amount of scattering were found. In 1963 at stations 25 and 50 miles off Newport, Oregon, more scattering was present during the summer than the winter. Seasonal variations were not as evident in 1964. North of Hawaii, near 47°N Latitude, a marked decrease of scattering occurred in the summer of 1966. Corresponding with this decrease in scattering was a somewhat higher biomass in midwater trawl collections.

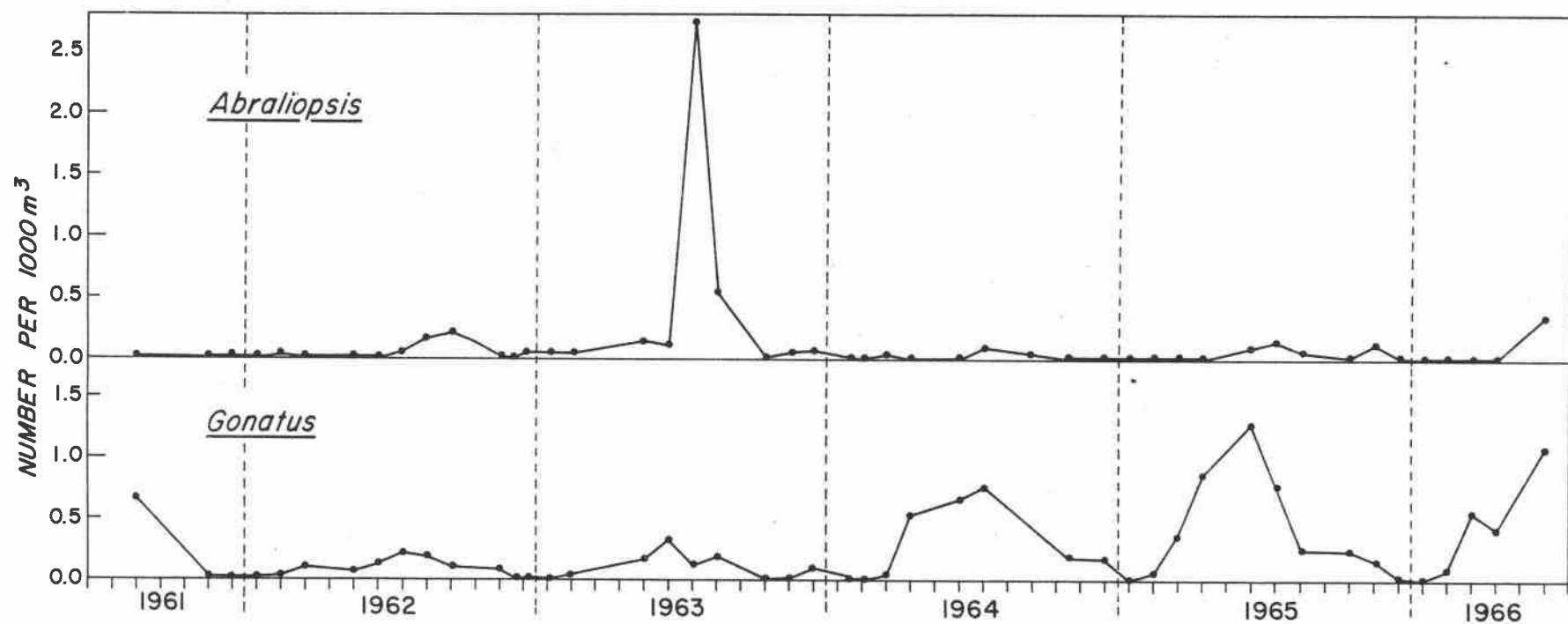


Figure 1. Catches of the two common squids off Newport, Oregon, 1961-1966.

Vertical Migration and Distribution of Pelagic Animals - Percy, Mesecar, Smiles

Differences between the day and night catches of many species of oceanic animals emphasize one of the major problems in quantitatively assessing either vertical migrations or standing stocks of motile organisms.

We are comparing the catches of various species from different types of nets towed during daylight and darkness. A total of 48 plankton net and 60 midwater trawl collections were made during the past six months for this purpose. A conducting cable system is being developed to facilitate this type of research.

Benthic Ecology - Carey, Alspach, Hufford, Hancock

Members of the benthic ecology and radioecology group participated in three cruises off the coast of Oregon during the report period. Samples taken included 27 otter trawls, 11 anchor-box dredges, 24 Smith-McIntyre bottom grabs, 27 bottom water samples and temperatures, and 2 beam trawl trials. Otter trawl and grab samples were collected on both the Newport and Tillamook Head station lines; anchor-box dredge samples were obtained on the Newport Hydrographic Line (NH Line).

A Fjarlie water bottle and deep-sea reversing thermometer equipped with a bottom trip device were mounted on the Smith-McIntyre grab frame for collection of physical and chemical environmental information. Useful data on temperature and salinity have been obtained from standard benthos stations.

The use of deep-sea camera systems has been initiated for the study of the abundance, distribution, and orientation of the larger epifauna as well as the microtopography of the benthic environment. An EG and G camera system was purchased jointly with Drs. Kulm and Fowler (see Geology Section), and much of the camera work will be undertaken jointly with the geology group. During a short trial cruise, we were able to position the camera accurately in relation to the bottom. Excellent photographs of bottom shrimp and sediment were taken on the cruise.

Analyses of the density and biomass of the small macrofauna from biological stations on the NH Line continue; a summary of the work is being prepared for publication. Some preliminary results indicate that biomass and abundance appear to vary with depth and with distance from shore in a similar manner (Figure 2). Estimates of the organic carbon, as a measure of the potential food sources of the deposit-feeding infauna, have been

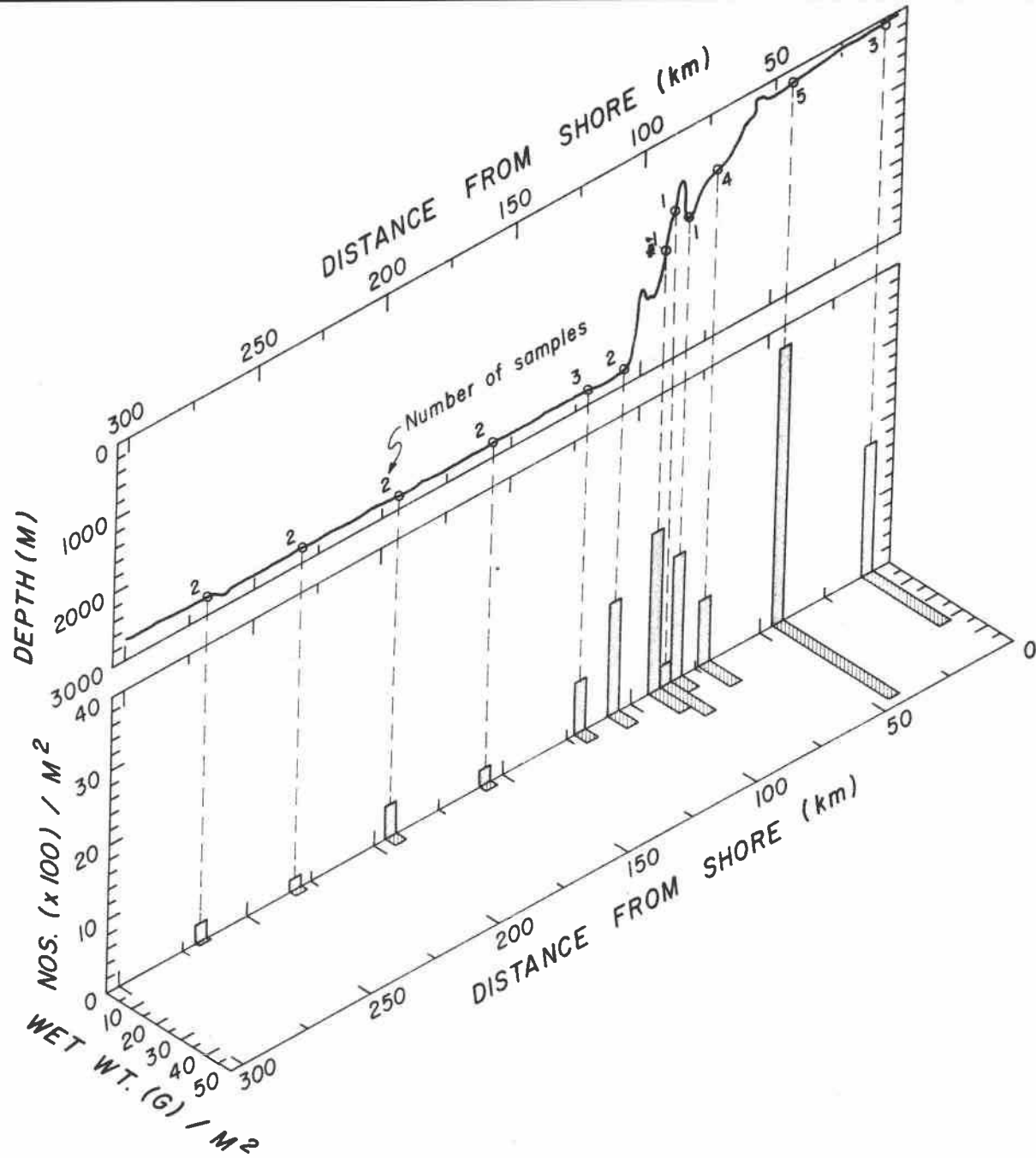


Figure 2. Comparison of biomass and abundance along the Newport Station Line.

made for sediments at the biological stations. There does not appear to be a direct relationship of the faunal abundance or biomass with organic carbon along the entire station line (Figure 3); a more accurate measure of usable food sources is necessary. There are five stations where average faunal abundance exceeds 1500 animals per square meter. These areas of marked abundance occur: (a) near shore at 25 m depth; (b) at the edge of the shelf at 200 m depth; (c) at the bottom of the first slope valley at 1250 m depth; and (e) at the bottom of the slope on Cascadia Abyssal Plain at 2860 m depth.

#### Reproduction of Echinoderms - Hufford, Carey

A study of the reproductive activity of the abyssal holothurian Paelopatides sp. is nearing completion. Preliminary results indicate that a portion of the adult animals reproduce throughout the year; at any one time 25% are sexually mature, 57% immature, and 18% in spent condition. The relation of temperature, salinity, and food supply to reproductive activity is being investigated. Temperature and salinity do not seem to vary significantly at depth (2860 m) during the year. Organic carbon content of sediment at NH-65 has been studied. The organic content by weight of the sediment surface is about 4%, while the upper 1 cm of sediment averages 2%.

#### Systematics of Deep-Sea Trematodes - McCauley

The systematics of trematodes of the genus Lepidapedon have been studied, and six new species are recognized in Oregon waters. Most of these came from macrourid fishes, but one species is associated with gadid fishes. The different species of trematodes appear to show some host specificity. Furthermore, among the various species in the genus, morphological characteristics seem to vary somewhat with the temperature distribution of the host. Most notably, the excretory bladder of trematodes in this genus seems to be shorter in species of cold water fishes than in species of warm water fishes.

#### Distribution and Ecology of Oregon Echinoids - McCauley, Carey

Brisaster townsendi has been carefully studied and placed in synonymy with B. latifrons. This species is widespread along the west coast of North America in 50-800 meters of water. Both names have been used, and much confusion has arisen about the taxonomy. Measurements and examination of more than 600 specimens failed to reveal any characteristic that could validly separate the species into distinct parts. Furthermore, descriptions in the literature did not agree completely with the specimens in the U. S. National Museum from which the descriptions were made.

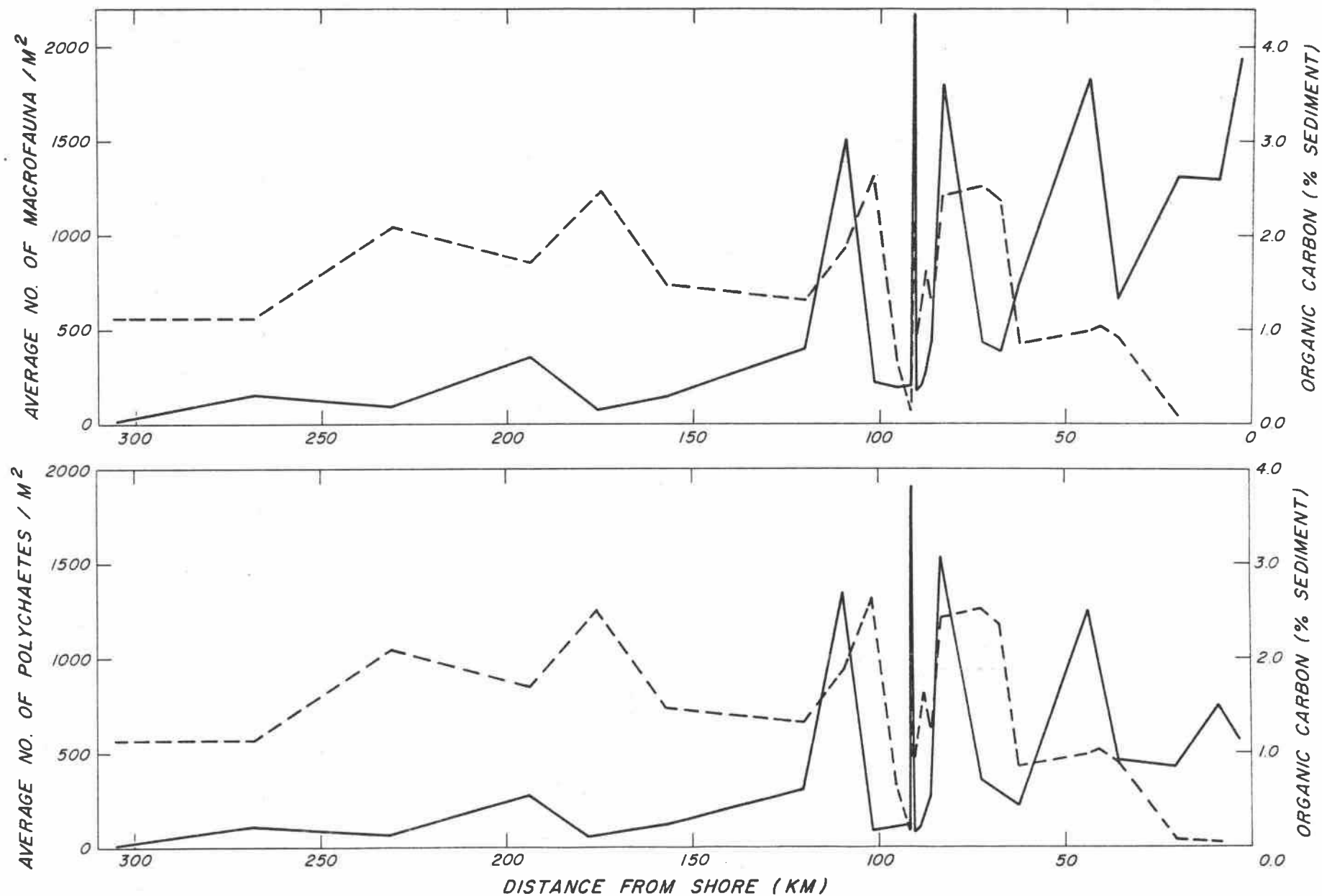


Figure 3. Relationship of fauna to sedimentary organic carbon.  
Upper: total average number of macrofauna.  
Lower: average number of polychaetes.

Two additional species of echinoids have been collected since the distributional study was completed, but these have not yet been studied.

#### Deep-Sea Fouling Studies - Tipper, McCauley

An initial array of pine and fir sample panels was subjected to biological deterioration on the ocean floor in 200 meters of water in November 1966. Approximately one month later it was successfully recovered.

Prior to further sampling, analysis of this first installation was carried out. Minor modifications in the mooring system design were made, principally to protect critical areas from failure due to mechanical chafing. The design of the sample panel rack proved most suitable in resisting corrosion and protecting the sample materials from loss or damage. Biological attack by marine boring molluscs was very prominent on all sample panels. Initial surface penetrations on the pine panels averaged over 100 borers per square centimeter; but density of attack on fir panels proved much lower, averaging about 7 borers per square centimeter.

This substantial amount of biological attack and the variation in attack on panel types seemed to justify a time-series analysis designed to study rates of attack on a variety of sample materials. Such a study was initiated early in January 1967, when two sample panel arrays were deployed on the same site for 50-day and 75-day exposures, respectively. The sample panel arrays carried 14 test materials including eight woods (pine, fir, oak, maple, ash, redwood, mahogany, and cedar); five plastics (acrylic, nylon, teflon, poly-vinyl-chloride, and poly-ethylene); and one metal (aluminum). These sample panel arrays were recovered in February and March of 1967, respectively. Initial surveys of the samples indicated both a high amount of biological deterioration caused by boring molluscs, and also a small group of associated crustacean and gastropod molluscan fouling organisms. Further detailed quantification of the amount of damage caused to each sample panel type and identification of boring and fouling organisms are now being carried out.

Progress is now underway on a spring and summer 1967 sampling program to involve deployment in mid May of seven additional sample panel arrays. Three arrays are to be located at depths less than 200 meters on the continental shelf in connection with current measurements over the shelf, see page 8. Four arrays are to be placed at a depth of 1000 meters on the continental slope. A late summer installation at a depth of 2800 meters is now being planned.

Mr. Pillsbury has assisted with the design and installation of all mooring systems. Considerable progress has been made in improving

mooring systems. Considerable progress has been made in improving the reliability of moderate -scope mooring systems by using synthetic line and small diameter toroidal surface floats.

#### Metabolism of Zinc-65 by Euphausiids - Small, Bergeron, Fowler

To supplement investigations on the biological role of zinc in marine food-chain organisms, we are studying uptake and retention of  $\text{Zn}^{65}$  from water and food by the pelagic crustacean, Euphausia pacifica. Experiments were performed at three temperatures ( $5^\circ$ ,  $10^\circ$ ,  $15^\circ\text{C}$ ) and at two concentrations of radiozinc (10 and  $25\mu\text{c/l}$ ). Uptake from the water (direct uptake) was dependent upon the water temperature, size of animal, and  $\text{Zn}^{65}$  concentration in the water. Weight-specific direct uptake was linear over a  $5\text{--}15^\circ\text{C}$  range. Weight-specific direct uptake and corrected concentration factors decreased as the weight of the euphausiid increased. Initial rates of elimination and biological half-lives were also dependent upon animal weight, temperature of the water, and  $\text{Zn}^{65}$  concentration in the euphausiid. Similar results were obtained in both direct uptake and elimination experiments by using dead euphausiids (formalin-preserved). Molting in live animals accounted for a large  $\text{Zn}^{65}$  loss, with the molted exoskeletons containing about 30% of the body burden. (Some of the above was reported in Progress Report 18). Results obtained by dissection of the tissues gave higher  $\text{Zn}^{65}$  percentages for the exoskeletons. Autoradiograms showed that the radionuclide was localized on the exoskeleton and between the muscle fibers. These results indicate that  $\text{Zn}^{65}$  accumulation by euphausiids directly from the water is primarily an adsorptive process.

Uptake through the food chain is being assessed by feeding  $\text{Zn}^{65}$ -labelled phytoplankton to E. pacifica. Rates of  $\text{Zn}^{65}$  assimilation are affected largely by water temperature and by  $\text{Zn}^{65}$  content of the food, though grazer size may also be a factor. In general, uptake through the food chain is slower than directly through the water but may ultimately allow higher concentrations of the isotope in the body.

#### Assimilation of Organic Matter by Marine Second Trophic Level Grazers - Small, O'Connors

Feeding experiments have been initiated with euphausiids in an attempt to estimate assimilation of organic matter from measurements of ingestion and egestion. Techniques and limits of the proposed methods are currently being worked out. We hope to expand this approach to other important pelagic filter feeders in the Pacific Ocean, particularly the copepods. Successful measurement of assimilation under different conditions will allow the prediction of energy flow, which can be compared to energy flow estimates made with a different technique.



### Energy Flow in Euphausiids - Small

Respiratory rates and growth rates have been combined to yield a first estimate of energy flow in euphausiids off Oregon. Respiratory rates as a function of temperature, and hence as a function of seasonal temperature changes and vertical migration of the animals, were available from over 100 measurements in a respirometer. Growth rates were estimated from size-frequency data supplied by Dr. Pearcy's group, but precision was only good enough to allow the calculation of one overall growth rate rather than seasonal rates as was desired. As energy flow is approximately equal to respiration plus growth, monthly estimates (on a g cal/"average" animal/day basis) could be made by summing respiration and growth estimates "weighted" by the size structure of the population. Energy flow on this basis was affected not only by population size structure (percentages of small, medium, and large animals) but also by water temperature and photoperiod. Energy flow on a g cal/mg/day basis allowed the assessment of the effects of temperature and photoperiod without regard to population size structure.

Annual energy flow is depicted in Figure 4. The increase in energy/"average" animal from January to early June 1965 was largely the result of an increase in weight of the "average" animal during this time. Integration of the area under the curves in Figure 4 yielded an annual energy flow of approximately 100 g cal/"average" animal (60 g cal/mg). If assimilation of ingested carbon by euphausiids is 84%, as reported in the literature, the "average" animal ingests roughly 15 mg C/yr, using the conversion of 8 g cal/mg C and assuming complete biological oxidation of all assimilated carbon. On a weight-specific basis, ingestion is about 9 mg C/mg/yr.

### Yaquina Bay Plankton Studies - Frolander, McCormick, Markham, Flynn

We continued to collect samples weekly from five stations in Yaquina Bay. A total of 190 Clarke-Bumpus tows with #6 and #12 mesh nets and 97 half-meter net tows with #6 mesh nets were taken. At each station, surface and bottom water samples were collected for determining temperature, salinity, and dissolved oxygen content.

A 24-hour temporal survey was conducted on 20 and 21 March at Buoy 21 in Yaquina Bay. Each hour two CB samples, one half-meter net sample, and four water samples were taken. On 23 March a spatial survey of the bay was made which included water and plankton samples taken at six stations in the bay.

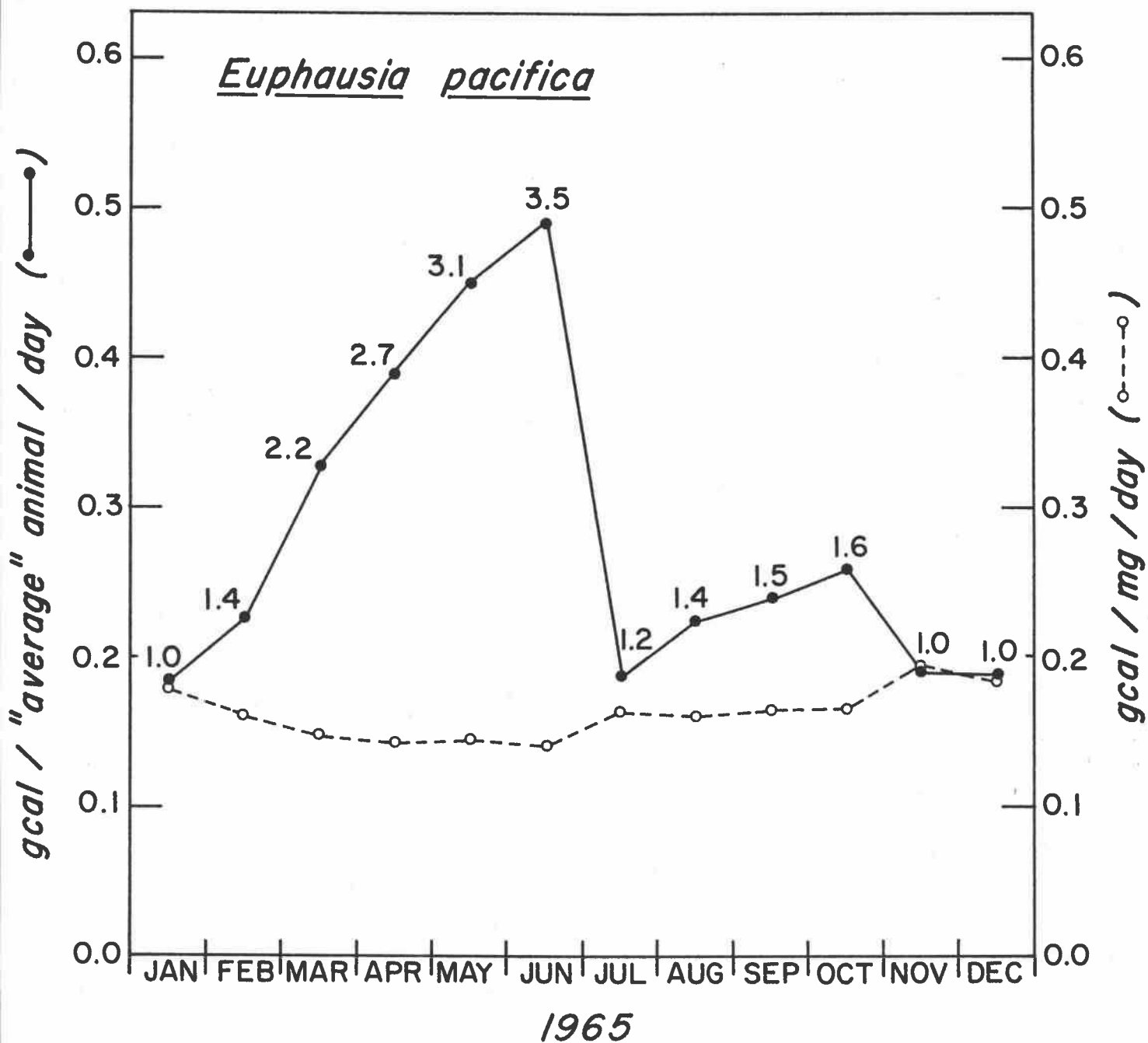


Figure 4. Energy flow in *E. pacifica*. The values beside the data points refer to the adjusted mean dry weight per animal (mg) in the respective months.

Gut contents of hydromedusae and ctenophores are being examined and the food organisms identified. This information will be related to the corresponding plankton and physical data for the sampling station. Monthly hydroid collections have been made since September 1966, and will be related to the medusoid forms found in the plankton.

Laminarian holdfasts have been collected at various stations in Yaquina Bay from July to December 1966. They are being studied to determine the spatial and temporal distribution of invertebrates inhabiting them.

#### Marine Microbiology - Morita

The effect of salt concentration was shown to influence the maximum growth temperature of Vibrio marinus from 10.5°C to slightly less than 20°C. In the same organism the synthesis of protein, RNA, and DNA was shown to be completely inhibited at 1,000 atm. At 200 atm. the rate of protein and RNA synthesis was decreased but quickly resumed the 1 atm. rate; DNA synthesis was not affected. At 500 atm. (75 atm. above the lethal pressure), the rate of protein synthesis immediately dropped to one-third the 1 atm. rate; RNA synthesis continued at the 1 atm. rate for 30 minutes before shifting to a lower rate; and DNA synthesis continued at the 1 atm. rate for 60 minutes before diminishing. It stopped completely after 150 minutes.

Thermally induced leakage of materials from cells of Vibrio marinus was found to be related to the age of the culture. Cells obtained in the log phase of growth were found to be less resistant to thermally induced leakage than cells obtained from the stationary phase.

#### Reproductive Cycles of Marine Invertebrates - Gonor

Investigations have been conducted on methods and equipment to be used in continuing studies on the relation between environmental temperatures and reproduction in marine invertebrates. Air and seawater temperature regimes from extreme high tide to the subtidal boundary will be studied by continuous temperature recording at several coastal stations. A review of both the available instrumentation and the problem has demonstrated that recording from permanently installed in situ thermistors by means of digital punched-tape recorders is the most feasible approach to the field data collecting problem. Specific methods for adaptation of available recorders are being investigated.

Laboratory investigations were conducted on artificial feeding and gonad biopsy of the sea urchin Strongylocentrotus purpuratus, selected for experimental study of the effect of photoperiod and temperature on gonad cycles. A solid artificial food acceptable to this species which will sustain it indefinitely was compounded of balanced laboratory animal diet and an agar binder. This food will permit the nutrition of experimental animals to be freed of seasonal influence. A successful pilot-controlled temperature and photoperiod aquarium apparatus for experimental work was constructed and tested for stability.

## DEGREES GRANTED

BUFFO, Lynn K. M.S., Radioecology

Thesis Title: Extraction of Zinc from Seawater.

Major Professor: Charles L. Osterberg

CARDER, Kendall L. M.S., Physical Oceanography

Thesis Title: Error Analysis of Interferometry in Measurement  
of Forward Scatter in Seawater.

Major Professor: Stephen Neshyba

CRANDELL, George F. M.S., Biological Oceanography

Thesis Title: Seasonal and Spatial Distribution of Harpacticoid  
Copepods in Relation to Salinity and Temperature  
in Yaquina Bay, Oregon.

Major Professor: Herbert F. Frolander

CUTSHALL, Norman H. Ph.D., Radioecology

Thesis Title: Chromium-51 in the Columbia River and Adjacent  
Pacific Ocean.

Major Professor: Charles L. Osterberg

FREDERICK, Lawrence C. Ph.D., Radioecology

Thesis Title: Dispersion of the Columbia River Plume Based on  
Radioactivity Measurements.

Major Professor: Charles L. Osterberg

HARDY, John T. M.S., Biological Oceanography

Thesis Title: Identification, Culture, and Physiological Ecology  
of Cryophilic Algae.

Major Professor: Herbert C. Curl, Jr.

LAURS, R. Michael. Ph.D., Biological Oceanography

Thesis Title: Coastal Upwelling and the Ecology of Lower Trophic  
Levels.

Major Professor: William G. Pearcy

## FACILITIES

### Marine Science Center

#### Aquarium

The program to improve and expand the aquarium at the Marine Science Center, Newport, Oregon, has continued through the winter and spring months. A filtration system permitting each major display tank to be individually filtered has been installed and functions to full expectations. An aeration system, connected to the laboratory compressed air supply, but with a back-up compressor, has been installed. Ventilation for the aquarium service room has been provided. Other modifications to improve safety, to increase building life, and to reduce service labor have been made.

Three major portions of the modification program are still underway. A large display tank 14 feet in length which will contain about 2,500 gallons is under contract. One new display panel providing space for six to eight medium or small tanks is under contract with two additional panels to follow. A fiberglass reinforced plastic reservoir of 2,000 gallon capacity, with a bank of six filters and a distribution pump, is under construction. This reservoir system supplies filtered water to the aquarium proper, to lobby tanks for the octopus and the intertidal displays, and to the new display panels. It has sufficient capacity to span water interruptions of up to 24 hours. These new facilities, to be in operation before the summer session begins, will complete the presently planned aquarium modifications.

#### Small Boat Marina

The small boat marina, located upstream of the main dock immediately in front of the main building, is nearing completion. A causeway with a 15-foot gravel roadway and turn-a-round and a cement-surfaced boat launching ramp have been completed. A 100-foot pier with a 15-foot wide deck is complete except for utilities. Four 20-foot mooring floats and a walk ramp are nearing completion. These floats provide six finger-slips sized to accommodate a variety of small craft, including the 33-foot PAIUTE.

The main dock has been modified by the addition of a 60-foot walk ramp and floating dock. This dock is intended primarily for loading and unloading of small craft but can provide additional mooring for two or three small crafts if needed.

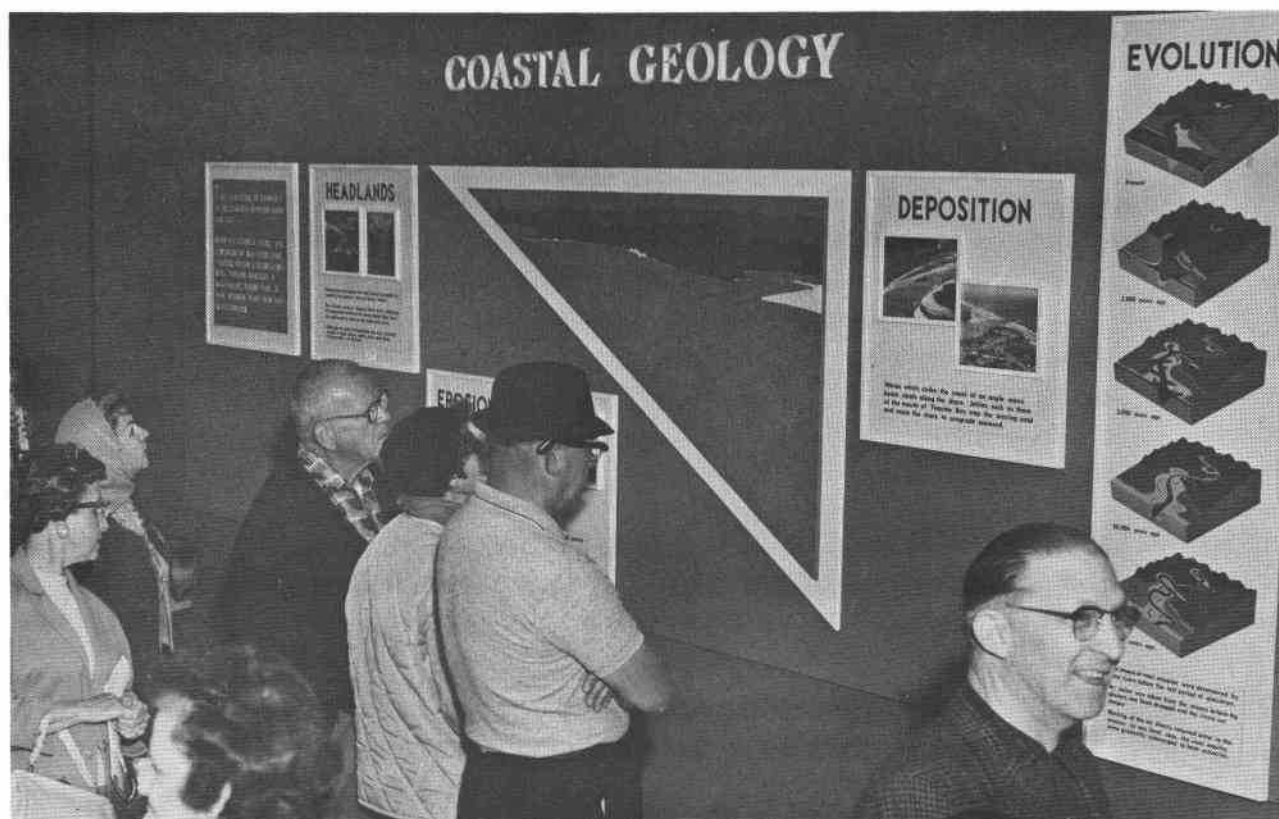


Figure 1. Coastal geology display panel at the Marine Science Center.



Figure 2. Marine exploration display panel at the Marine Science Center.

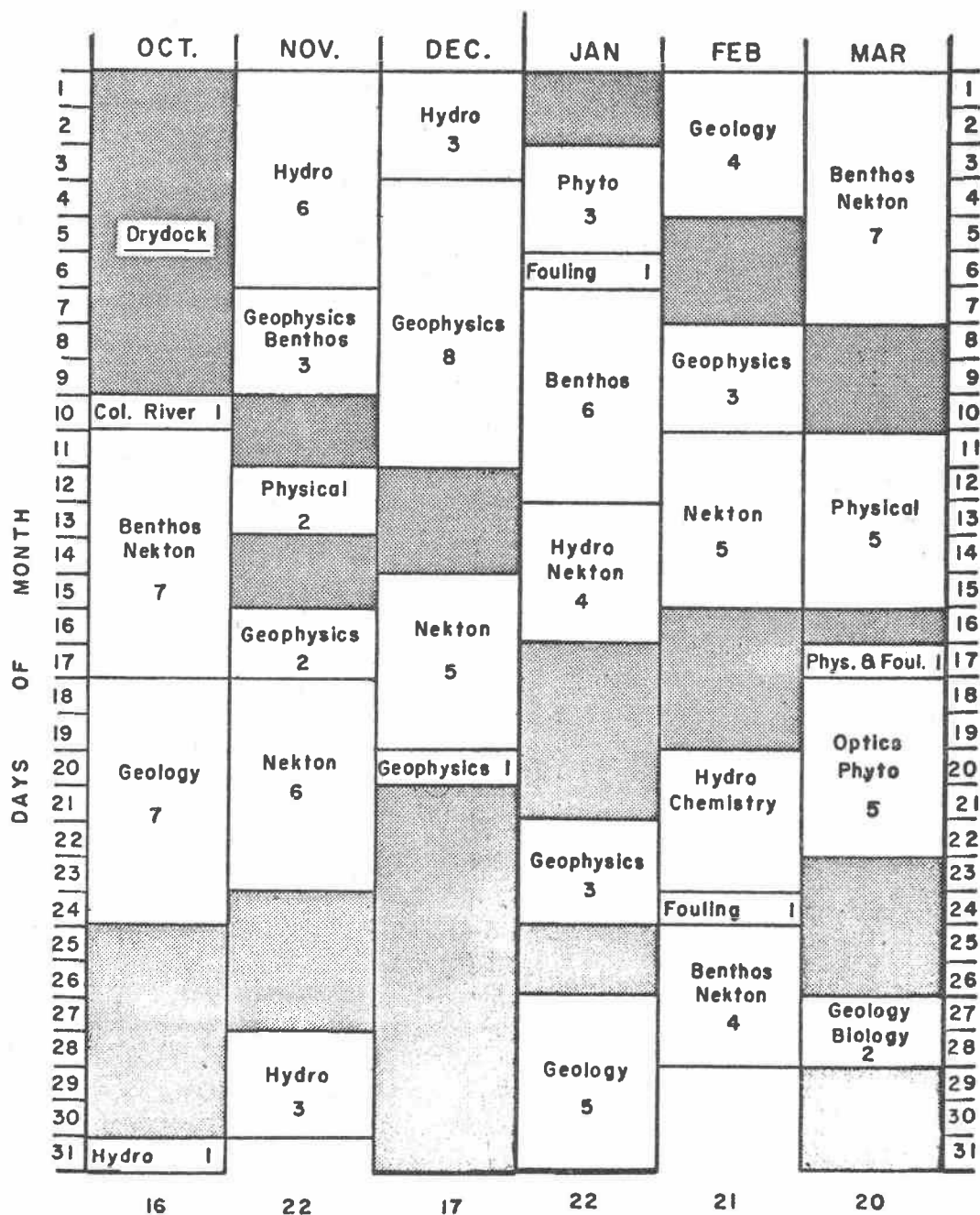


Figure 3. Time at sea - R/V YAQUINA.



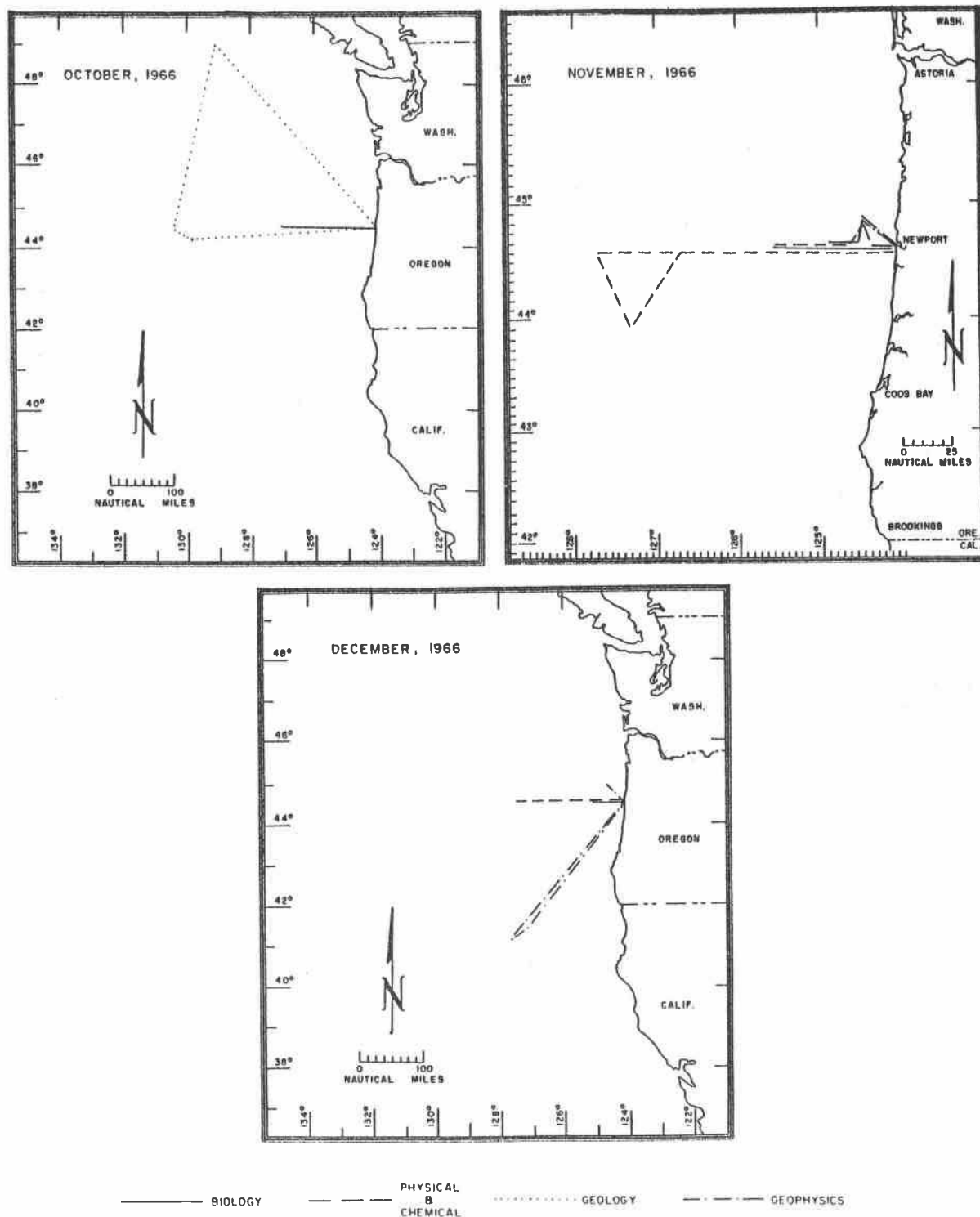


Figure 4. Cruise tracks of R/V YAQUINA, October 1966 - December 1966.

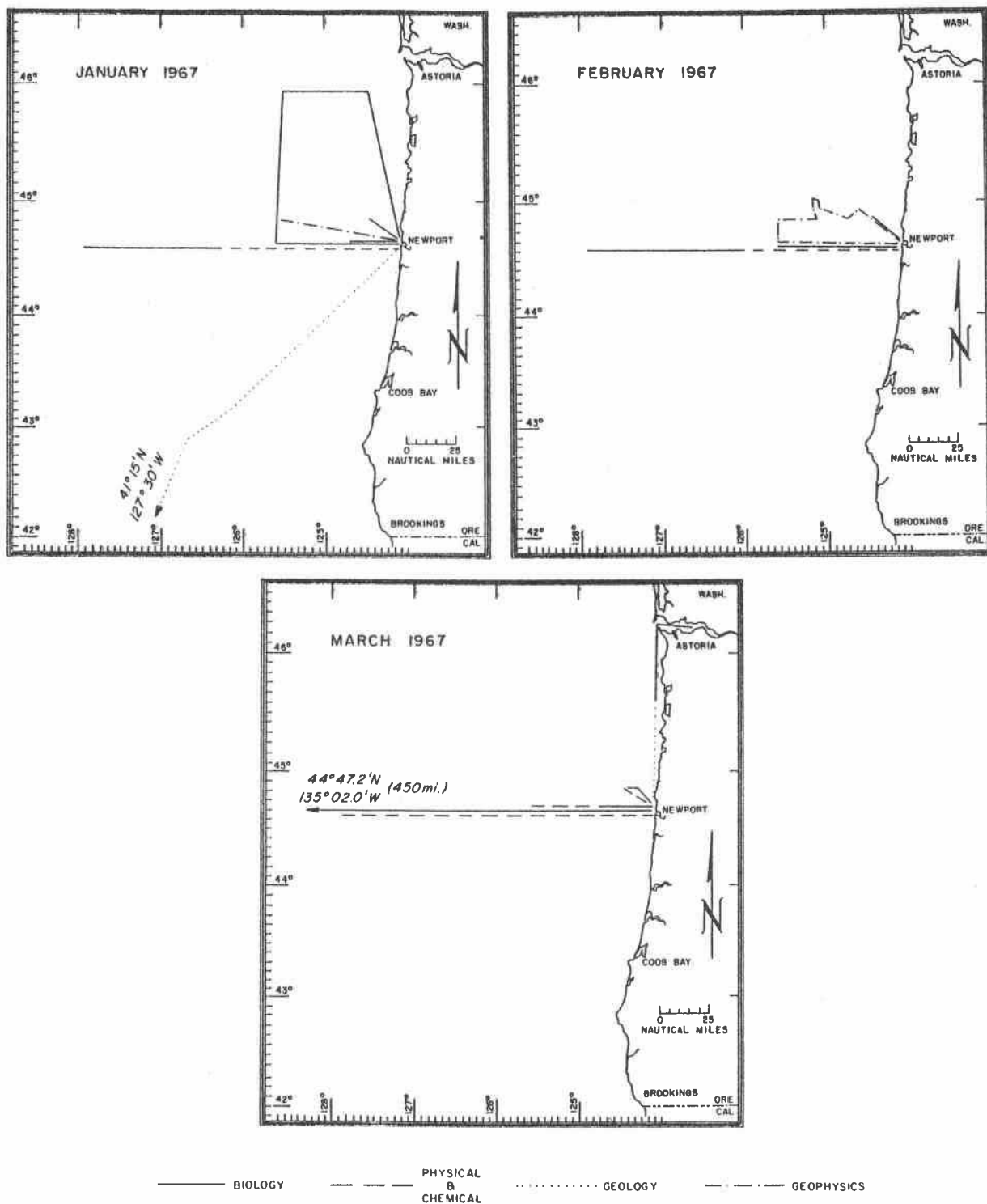


Figure 5. Cruise tracks of R/V YAQUINA, January 1967 - March 1967.

## STAFF

Dr. G. Stephen Pond, Assistant Professor of Physical Oceanography, has accepted an appointment with the Department of Oceanography beginning in May 1967.

Dr. Ricardo M. Pytkowicz has returned from a four-month trip to England, Belgium, and Sweden where he worked on research and toured laboratory facilities. The NSF-supported research project involving the physical chemistry of seawater under high pressure was carried out by Dr. Pytkowicz in collaboration with Professor A. Disteche, University of Liege, Belgium.

Using laboratory equipment to simulate the pressure of ocean depths, they studied the effect of this pressure on carbonic acid and on calcium carbonate. The project yielded information about the formation of sediments and limestone, the tracking of deep ocean currents, and the regeneration of nutrients from decaying organic matter.

Dr. David Tilles, Assistant Professor of Oceanography (Geochemistry), has accepted an appointment with the Department of Oceanography beginning in June 1967.

## VISITING SCIENTISTS

- October      Dr. David Tilles, Smithsonian Astrophysical Observatory and Harvard College Observatory. "Interplanetary dust, rare gases, and the history of ocean sediments."
- Dr. Tadashi Malba, Japanese Fisheries Agency.
- Mr. Roy Gaul, Westinghouse Undersea Laboratory, San Diego.
- Mr. Arthur Nelkin, Westinghouse Undersea Laboratory, San Diego.
- Mr. A. D. Watt, Research Director, Westinghouse's Boulder Laboratories.
- November    Mr. George Wilkins, U. S. Naval Ordnance Test Station, China Lake, California. "Permanent colonies under the sea."
- Dr. Robert K. Lane, Department of Mines and Technical Surveys, Canada.
- Dr. James Henry, Director of Marine Laboratory, University of Georgia, Athens, Georgia.
- Dr. Robert G. Paquette, Head, Physical Oceanography Group, General Motors Defense Research Laboratories, Santa Barbara, California. "Can oceanographers expect to buy fool-proof instruments?"
- December    Dr. Allen H. Schooley, Associate Director of Research for Special Projects, U. S. Naval Research Laboratory, Washington, D. C. "Evaporation rate measurements from a wind-disturbed water surface."
- Mr. Robert Beardsley, The Massachusetts Institute of Technology. "Time dependent instabilities in the Western Boundary Current."
- January      Dr. V. J. Linnenbom, Superintendent, Ocean Science and Engineering Division, U. S. Naval Research Laboratory, Washington, D. C. "Oceanographic researches at the U. S. Naval Research Laboratory."

Dr. J. W. Swinnerton, Chemical Oceanography Branch,  
U. S. Naval Research Laboratory, Washington, D. C.  
"On the determination of gaseous hydro-carbons in sea-  
water by gas chromatography."

Dr. Bernard Reimann, Director, Electron Microscopy Facil-  
ities, Scripps Institution of Oceanography. "The mor-  
phology of silica deposition in diatoms."

Dr. Warren Thompson, National Science Foundation, Washington,  
D. C.

February Dr. J. A. C. Nicol, The Plymouth Laboratory, England,  
"Bioluminescence of fishes."

Dr. John D. Isaacs, University of California, San Diego.  
"Ocean technology."

Dr. Robert Wall, Office of Naval Research, Washington, D. C.

Dr. Peter Dehlinger, Office of Naval Research, Washington, D. C.

Dr. M. S. Longuet-Higgins, F. R. S., National Institute of  
Oceanography, England, and Scripps Institution of  
Oceanography.

March Mr. Kenneth V. MacKenzie, Head Scientist, Deep Submergence  
Group, U. S. Naval Electronics Laboratory, San Diego.  
"Deep submersibles in oceanographic research."

Mr. David Rodenhuis, University of Washington. "Conditional  
instability in the tropical atmosphere."

Dr. Allan W. H. Bé, Lamont Geological Observatory, Columbia  
University, New York, N. Y.

## VISITING SCIENTISTS ABOARD R/V YAQUINA

- February      Dr. F. N. Dost, Assistant Professor of Pharmacy,  
Veterinary Medicine, Science Research Institute,  
Oregon State University. Cruise 6702-D, Fouling,  
McCauley.
- Dr. J. A. C. Nicol, The Plymouth Laboratory,  
England. Cruise 6702-B, Nekton, Percy.
- Dr. D. J. Reed, Associate Professor of Chemistry,  
Radiation Center, Oregon State University.  
Cruise 6702-D, Fouling, McCauley.

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- Bodvarsson, G. Thermal activity, Geyser, Solfatara, and Fumarole. Encyclopedia of Earth Science.
- Bodvarsson, G. Some considerations on the optimum production and use of geothermal energy.
- Bodvarsson, G. and D. J. Ryley. The measurement of the weight discharge from geothermal steam wells.
- Carey, A. G. Radioecology of marine benthic invertebrates off the coast of Oregon. Second National Symposium on Radioecology - Ann Arbor.
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- Curl, H. C. Jr., and E. Davey. Improved sample-injection systems for non-destructive analysis of permanent gases, total CO<sub>2</sub> and dissolved organic carbon in water. Limnol. Oceanogr.
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- Fowler, S. W. and L. F. Small. Moulting of Euphausia pacifica as a possible mechanism for transport of zinc-65 in the sea. Nature.
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- Heinrichs, D. F. Paleomagnetism of the Plio-Pleistocene Lousetown Formation, Virginia City, Nevada. J. Geophys. Res.
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## PAPERS PRESENTED AT SCIENTIFIC MEETINGS

- Beardsley, G. F., Jr. The Mueller scattering matrix of seawater. Optical Society of America. San Francisco, California. October 1966.
- Boettcher, R. S. and G. A. Fowler. Ecology of central Oregon shelf foraminifera. Oregon Academy of Science. Salem, Oregon. February 1967.
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- Carey, A. G., Jr. Biological oceanography at Oregon State University. Pacific Northwest Oceanographers. Victoria, B. C. February 1967.
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- Park, K. Chemical oceanography at Oregon State University. Pacific Northwest Oceanographers. Victoria, B. C. February 1967.
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